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OF
WASHINGTON

YEAR BOOK
No. 10

1911

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ROBERT S. WOODWARD

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SETH LOW, *Chairman*
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HENRY L. HIGGINSON

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* Ex-officio member.

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ARTICLES OF INCORPORATION.

The Carnegie Institution was originally organized under the law governing the organization of corporations in the District of Columbia. Owing to certain limitations in the law, the Trustees deemed it desirable to obtain articles of incorporation from the Congress. Accordingly, articles of incorporation were prepared, submitted to the Congress, amended by the Congress, and enacted into statute by the Congress and the signature of the President.

Organization under the new articles of incorporation was effected on May 18, 1904. Resolutions were passed electing the same Executive Committee and officers as those of the Carnegie Institution organized in 1902 and continuing all instructions and authorizations given to the Executive Committee by the old organization.

PUBLIC No. 260.—An Act To incorporate the Carnegie Institution of Washington.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the persons following, being persons who are now trustees of the Carnegie Institution, namely, Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, their associates and successors, duly chosen, are hereby incorporated and declared to be a body corporate by the name of the Carnegie Institution of Washington and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions herein contained.

SEC. 2. That the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind; and in particular—

(a) To conduct, endow, and assist investigation in any department of science, literature, or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies, and individuals.

(b) To appoint committees of experts to direct special lines of research.

(c) To publish and distribute documents.

(d) To conduct lectures, hold meetings and acquire and maintain a library.

(e) To purchase such property, real or personal, and construct such building or buildings as may be necessary to carry on the work of the corporation.

(f) In general, to do and perform all things necessary to promote the objects of the institution, with full power, however, to the trustees hereinafter appointed and their successors from time to time to modify the conditions and regulations under which the work shall be carried on, so as to secure the application of the funds in the manner best adapted to the conditions of the time, provided that the objects of the corporation shall at all times be among the foregoing or kindred thereto.

SEC. 3. That the direction and management of the affairs of the corporation and the control and disposal of its property and funds shall be vested in a board of trustees, twenty-two in number, to be composed of the following individuals: Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, who shall constitute the first board of trustees. The board of trustees shall have power from time to time to increase its membership to not more than twenty-seven members. Vacancies occasioned by death, resignation, or otherwise shall be filled by the remaining trustees in such manner as the by-laws shall prescribe; and the persons so elected shall thereupon become trustees and also members of the said corporation. The principal place of business of the said corporation shall be the city of Washington, in the District of Columbia.

SEC. 4. That such board of trustees shall be entitled to take, hold and administer the securities, funds, and property so transferred by said Andrew Carnegie to the trustees of the Carnegie Institution and such other funds or property as may at any time be given, devised, or bequeathed to them, or to such corporation, for the purposes of the trust; and with full power from time to time to adopt a common seal, to appoint such officers, members of the board of trustees or otherwise, and such employees as may be deemed necessary in carrying on the business of the corporation, at such salaries or with such remuneration as they may deem proper; and with full power to adopt by-laws from time to time and such rules or regulations as may be necessary to secure the safe and convenient transaction of the business of the corporation; and with full power and discretion to deal with and expend the income of the corporation in such manner as in their judgment will best promote the objects herein set forth and in general to have and use all powers and authority necessary to promote such objects and carry out the purposes of the donor. The said trustees shall have further power from time to time to hold as investments the securities hereinabove referred to so transferred by Andrew Carnegie, and any property which has been or may be transferred to them or such corporation by Andrew Carnegie or by any other person, persons, or corporation, and to invest any sums or amounts from time to time in such securities and in such form and manner as are permitted to trustees or to charitable or literary corporations for investment, according to the laws of the States of New York, Pennsylvania, or Massachusetts, or in such securities as are authorized for investment by the said deed of trust so executed by Andrew Carnegie, or by any deed of gift or last will and testament to be hereafter made or executed.

SEC. 5. That the said corporation may take and hold any additional donations, grants, devises, or bequests which may be made in further support of the purposes of the said corporation, and may include in the expenses thereof the personal expenses which the trustees may incur in attending meetings or otherwise in carrying out the business of the trust, but the services of the trustees as such shall be gratuitous.

SEC. 6. That as soon as may be possible after the passage of this Act a meeting of the trustees hereinbefore named shall be called by Daniel C. Gilman, John S. Billings, Charles D. Walcott, S. Weir Mitchell, John Hay, Elihu Root, and Carroll D. Wright, or any four of them, at the city of Washington, in the District of Columbia, by notice served in person or by mail addressed to each trustee at his place of residence; and the said trustees, or a majority thereof, being assembled, shall organize and proceed to adopt by-laws, to elect officers and appoint committees, and generally to organize the said corporation; and said trustees herein named, on behalf of the corporation hereby incorporated, shall thereupon receive, take over, and enter into possession, custody, and management of all property, real or personal, of the corporation heretofore known as the Carnegie Institution, incorporated, as hereinbefore set forth under "An Act to establish a Code of Law for the District of Columbia, January fourth, nineteen hundred and two," and to all its rights, contracts, claims, and property of any kind or nature; and the several officers of such corporation, or any other person having charge of any of the securities, funds, real or personal, books or property thereof, shall, on demand, deliver the same to the said trustees appointed by this Act or to the persons appointed by them to receive the same; and the trustees of the existing corporation and the trustees herein named shall and may take such other steps as shall be necessary to carry out the purposes of this Act.

SEC. 7. That the rights of the creditors of the said existing corporation known as the Carnegie Institution shall not in any manner be impaired by the passage of this Act, or the transfer of the property hereinbefore mentioned, nor shall any liability or obligation for the payment of any sums due or to become due, or any claim or demand, in any manner or for any cause existing against the said existing corporation, be released or impaired; but such corporation hereby incorporated is declared to succeed to the obligations and liabilities and to be held liable to pay and discharge all of the debts, liabilities, and contracts of the said corporation so existing to the same effect as if such new corporation had itself incurred the obligation or liability to pay such debt or damages, and no such action or proceeding before any court or tribunal shall be deemed to have abated or been discontinued by reason of the passage of this Act.

Sec. 8. That Congress may from time to time alter, repeal, or modify this Act of incorporation, but no contract or individual right made or acquired shall thereby be divested or impaired.

Sec. 9. That this Act shall take effect immediately.

Approved, April 28, 1904.

BY-LAWS OF THE INSTITUTION.

Adopted December 13, 1904. Amended December 13, 1910.

Article I.

THE TRUSTEES.

1. The Board of Trustees shall consist of twenty-four members, with power to increase its membership to not more than twenty-seven members. The Trustees shall hold office continuously and not for a stated term.

2. In case any Trustee shall fail to attend three successive annual meetings of the Board he shall thereupon cease to be a Trustee.

3. No Trustee shall receive any compensation for his services as such.

4. All vacancies in the Board of Trustees shall be filled by the Trustees by ballot. Sixty days prior to an annual or a special meeting of the Board, the President shall notify the Trustees by mail of the vacancies to be filled and each Trustee may submit nominations for such vacancies. A list of the persons so nominated, with the names of the proposers, shall be mailed to the Trustees thirty days before the meeting, and no other nominations shall be received at the meeting except with the unanimous consent of the Trustees present. Vacancies shall be filled from the persons thus nominated, but no person shall be declared elected unless he receives the votes of two-thirds of the Trustees present.

Article II.

MEETINGS.

1. The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the first Friday following the second Thursday of December in each year.

2. Special meetings of the Board may be called by the Executive Committee by notice served personally upon, or mailed to the usual address of, each Trustee twenty days prior to the meeting.

3. Special meetings shall, moreover, be called in the same manner by the Chairman upon the written request of seven members of the Board.

Article III.

OFFICERS OF THE BOARD.

1. The officers of the Board shall be a Chairman of the Board, a Vice-Chairman, and a Secretary, who shall be elected by the Trustees, from the members of the Board, by ballot to serve for a term of three years. All vacancies shall be filled by the Board for the unexpired term; provided, however, that the Executive Committee shall have power to fill a vacancy in the office of Secretary to serve until the next meeting of the Board of Trustees.

2. The Chairman shall preside at all meetings and shall have the usual powers of a presiding officer.

3. The Vice-Chairman, in the absence or disability of the Chairman, shall perform his duties.

4. The Secretary shall issue notices of meetings of the Board, record its transactions, and conduct that part of the correspondence relating to the Board and to his duties. He shall execute all deeds, contracts or other instruments on behalf of the corporation, when duly authorized.

ARTICLE IV.

EXECUTIVE ADMINISTRATION.

The President.

1. There shall be a President who shall be elected by ballot by, and hold office during the pleasure of, the Board, who shall be the chief executive officer of the Institution. The President, subject to the control of the Board and the Executive Committee, shall have general charge of all matters of administration and supervision of all arrangements for research and other work undertaken by the Institution or with its funds. He shall devote his entire time to the affairs of the Institution. He shall prepare and submit to the Board of Trustees and to the Executive Committee plans and suggestions for the work of the Institution, shall conduct its general correspondence and the correspondence with applicants for grants and with the special advisers of the Committee, and shall present his recommendations in each case to the Executive Committee for decision. All proposals and requests for grants shall be referred to the President for consideration and report. He shall have power to remove and appoint subordinate employees and shall be *ex officio* a member of the Executive Committee.

2. He shall be the legal custodian of the seal and of all property of the Institution whose custody is not otherwise provided for. He shall affix the seal of the corporation whenever authorized to do so by the Board of Trustees or by the Executive Committee or by the Finance Committee. He shall be responsible for the expenditure and disbursement of all funds of the Institution in accordance with the directions of the Board and of the Executive Committee, and shall keep accurate accounts of all receipts and disbursements. He shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board.

3. He shall attend all meetings of the Board of Trustees.

ARTICLE V.

COMMITTEES.

1. There shall be the following standing Committees, viz, an Executive Committee and a Finance Committee.

2. The Executive Committee shall consist of the Chairman and Secretary of the Board of Trustees and the President of the Institution *ex officio* and, in addition, five trustees to be elected by the Board by ballot for a term of three years, who shall be eligible for re-election. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term: Provided, however, that of the Executive Committee first elected after the adoption of these by-laws two shall serve for one year, two shall serve for two years, and one shall serve for three years; and such Committee shall determine their respective terms by lot.

3. The Executive Committee shall, when the Board is not in session and has not given specific directions, have general control of the administration of the affairs of the corporation and general supervision of all arrangements for administration, research, and other matters undertaken or promoted by the Institution; shall appoint advisory committees for specific duties; shall determine all payments and salaries; and keep a written record of all transactions and expenditures and submit the same to the Board of Trustees at each meeting, and it shall also submit to the Board of Trustees a printed or typewritten report of each of its meetings, and at the annual meeting shall submit to the Board a report for publication.

4. The Executive Committee shall have general charge and control of all appropriations made by the Board.

5. The Finance Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

6. The Finance Committee shall have custody of the securities of the corporation and general charge of its investments and funds, and shall care for and dispose of the same subject to the directions of the Board of Trustees and of the Executive Committee. It shall consider and recommend to the Board from time to time such measures as in its opinion will promote the financial interests of the Institution, and shall make a report at each meeting of the Board.

7. All vacancies occurring in the Executive Committee and the Finance Committee shall be filled by the Trustees at the next regular meeting.

8. The terms of all officers and of all members of committees shall continue until their successors are elected or appointed.

ARTICLE VI.

FINANCIAL ADMINISTRATION.

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Board of Trustees.

2. The fiscal year of the Institution shall commence on the first day of November in each year.

3. The Executive Committee, at least one month prior to the annual meeting in each year, shall cause the accounts of the Institution to be audited by a skilled accountant, to be appointed by the Board of Trustees, and shall submit to the annual meeting of the Board a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year.

4. The Board of Trustees, at the annual meeting in each year, shall make general appropriations for the ensuing fiscal year; but nothing contained herein shall prevent the Board of Trustees from making special appropriations at any meeting.

5. The securities of the Institution and evidences of property shall be deposited in such safe deposit or other corporation and under such safeguards as the Trustees and Executive Committee shall designate; and the moneys of the Institution shall be deposited in such banks or depositories as may from time to time be designated by the Executive Committee.

Article VII.

AMENDMENT OF BY-LAWS.

1. These by-laws may be amended at any annual or special meeting of the Board of Trustees by a two-thirds vote of the members present, provided written notice of the proposed amendment shall have been served personally upon, or mailed to the usual address of, each member of the Board twenty days prior to the meeting.

MINUTES

OF THE

Ninth and Tenth Meetings of the Board of Trustees

I

ABSTRACT OF MINUTES OF NINTH MEETING OF BOARD OF TRUSTEES.

A special meeting was held in New York, N. Y., at the Hotel Belmont, on Saturday, February 18, 1911, and was called to order at 12 o'clock noon by the chairman, Mr. Billings.

Upon roll-call by the secretary, the following members of the Board were found to be present: John S. Billings, Robert S. Brookings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Simon Flexner, Henry L. Higginson, S. Weir Mitchell, Andrew J. Montague, Henry S. Pritchett, Elihu Root, Charles D. Walcott, Henry P. Walcott, William H. Welch, Andrew D. White, George W. Wickersham, Robert S. Woodward.

The minutes of the eighth meeting were approved as printed in abstract.

Mr. Root read Mr. Carnegie's letter of gift, dated January 19, 1911, and it was

Resolved, That in accepting the gift from Mr. Carnegie of an increase of Ten Million Dollars to the Endowment of the Carnegie Institution of Washington the Board of Trustees desire to record their grateful appreciation of this additional expression of the Founder's wisdom in the advancement of research and of this additional testimony of confidence in the efforts of the Trustees and investigators of the Institution to increase the stock of fundamental knowledge and to render it available and useful to all mankind.

Provision was made for the opening of a Reserve Fund Account of the Institution, an additional appropriation of $30,000 was made available for use at the Mount Wilson Solar Observatory, and a contingent appropriation of $50,000 was authorized for expenditure at the discretion of the Executive Committee. The secretary read a detailed report submitted by the Finance Committee with respect to the securities held by the Institution.

The Board adjourned at 1 o'clock p. m.

ABSTRACT OF MINUTES OF TENTH MEETING OF BOARD OF TRUSTEES.

The meeting was held in Washington, in the Board Room of the Administration Building, on Friday, December 15, 1911, and was called to order at 10 o'clock a. m. by the chairman, Mr. Billings.

Upon roll-call by the secretary, the following Trustees responded: John S. Billings, Robert S. Brookings, John L. Cadwalader, Cleveland H. Dodge, Simon Flexner, William N. Frew, Henry L. Higginson, Charles L. Hutchinson, Seth Low, S. Weir Mitchell, Andrew J. Montague, William W. Morrow, Wm. Barclay Parsons, Elihu Root, Martin A. Ryerson, Charles D. Walcott, Henry P. Walcott, William H. Welch, Andrew D. White, George W. Wickersham, Robert S. Woodward.

The minutes of the ninth meeting were approved as printed in abstract and submitted to members of the Board of Trustees.

The reports of the President, the Executive Committee, the auditor, directors of departments, and grantees of the Institution, and a special report of the Finance Committee were presented and considered.

The following general appropriations for 1912 were authorized:

Administration	$50,000
Publication	60,000
Division of Publications	10,000
Departments of Research	631,000
Minor Grants	109,900
Index Medicus	12,500
Insurance Fund	23,000
Reserve Fund	250,000
Contingent Fund	50,000
	1,196,600

Provision was made for the permanent establishment of an Insurance Fund and for the yearly addition of appropriate sums thereto.

General questions of a financial nature were referred to a joint committee, consisting of the members of the Executive Committee and the Finance Committee, for consideration and report at the next meeting of the Board.

Messrs. Root and C. D. Walcott were elected to succeed themselves as members of the Executive Committee for a term of three years.

The Board adjourned at 1:30 p. m.

REPORT OF THE PRESIDENT

OF THE

CARNEGIE INSTITUTION OF WASHINGTON

FOR THE YEAR ENDING OCTOBER 31, 1911.

REPORT OF THE PRESIDENT OF THE CARNEGIE INSTITUTION OF WASHINGTON.

In conformity with Article IV of the By-laws of the Carnegie Institution of Washington, I have the honor to submit the following report on the history and on the progress of the work of the Institution for the fiscal year ending October 31, 1911, along with recommendations of appropriations for the ensuing year and with sundry suggestions concerning other matters of general or special interest.

This report is the tenth annual report of the Institution and is presented under the following principal heads:

1. Work of administration.
2. Résumé of investigations of the year.
3. Publications.
4. Recommendations of budget for 1912.

ADMINISTRATION.

Increase in Institution's Endowment.

The most important event in the history of the Institution during the past year is that of a new gift by the Founder of $10,000,000 to be added to the endowment of the Institution. This gift was made known by the following letter, which, although given to the press in February last, is here reproduced for more permanent record:

> New York, *January 19, 1911.*
>
> Dear Mr. President:
>
> So great has been the success of the Institution that I hav decided to increas its resources by adding Ten Millions of Five Per Cent Bonds, value Eleven and a Half Millions, which will ultimately giv you Five Hundred Thousand Dollars a year increast revenue. I stipulate as a condition of this gift that, unless expressly relieved therefrom by me, you shall set apart annually for the next ten years a sum not less than Two Hundred and Fifty Thousand Dollars in cash each year to be held in a reserv fund as against losses, emergencies, reduction in income, and the diminishing purchasing power of money. This will also giv the Board more time to study suggestions submitted to it and avoid the danger of premature action. Better that new ideas should be tested upon a small scale before going deeply into them.
>
> I hope the work at Mount Wilson will be vigorously pusht, becaus I am so anxious to hear the expected results from it. I should like to be satisfied before I depart, that we are going to repay to the

old land some part of the det we owe them by revealing more clearly than ever to them the new heavens.

Congratulating you and your fellow-members upon the undouted success of your labors,

Very gratefully to one and all of you,
(Signed) ANDREW CARNEGIE

DR. ROBERT S. WOODWARD,
PRESIDENT, CARNEGIE INSTITUTION,
WASHINGTON, D. C.

The Executive Committee authorized the acceptance of this gift at a special meeting held January 24, 1911. The bonds representing the amount were received by the Institution January 26, and on February 18 the Board of Trustees, at a special meeting called for the purpose, took such action as was necessary to give effect to the terms and conditions of the gift. Including the amount of $10,000,000 given at the time of foundation, January 29, 1902, and the addition of $2,000,000 given December 4, 1907, the total endowment of the Institution is now $22,000,000, yielding an annual income of $1,100,000.

In view of existing economic conditions, to which repeated reference has been made in previous reports, the requirement that half of the income from the recent addition to the endowment be set aside as a reserve fund for a period of ten years appears to be both wise and timely; for, although the Institution has fallen somewhat short of popular expectations in the rapidity of its growth and in the distribution of its income, it has nevertheless grown very rapidly in comparison with similar establishments and has already recognized the dangers of that pressure of poverty which is sometimes held to be a normal condition of educational institutions. But now that the preliminary stages of organization and development in the Institution have been passed, it is plainly evident that efficiency of research in the future may be most advantageously secured by means of more carefully laid plans and by less urgent procedure.

Other Salient Events of the Year.

In close connection with the event just related, it is a special source of pleasure to record that the Institution was enabled to secure, early in the year, an excellent portrait of the Founder, painted by Orlando Rouland, of New York. This portrait was designed, by the advice of Messrs. Carrère and Hastings, architects of the Administration Building, to fit the panel over the mantel in the Board Room, and was there installed on April 17, 1911.

Two other events of the year are worthy of special mention here, namely, the completion of the meridian work of the Department of Meridian Astrometry at the temporary observatory at San Luis, Argentina; and the construction of a capacious and efficient boat for the Department of Marine Biology.

It will be recalled that work of observing was begun at San Luis, Argentina, in April, 1909. This work was completed in January, 1911, and the party of observers returned with their instruments to the Dudley Observatory, Albany, N. Y., during the months April to June. The amount of work accomplished in this brief space of time is quite unparalleled in the annals of astronomy. This signal success is attributable chiefly to the carefully matured plans of the Director of the Department and to the highly trained corps of observers who carried out those plans. Great credit is due to Prof. R. H. Tucker, astronomer in charge of the corps, for his rapid and effective accomplishment of so arduous an enterprise. It is fitting, also, in this connection, to again acknowledge our indebtedness to the officials of the Argentine Government for uniform courtesy and for very substantial aid in the complex business incident to the expedition. In illustration of this admirable spirit and of the cosmopolitan appreciation of astronomical science, it is likewise worthy of record that, on the completion of the work in question, the citizens of San Luis gave a dinner in honor of Professor Tucker and presented to him a gold medal happily designed to commemorate the scientific and the humanistic importance of the event. As an additional memento of the occasion and as a more general expression of appreciation and good-will, the seventy-seven participants at the dinner signed an address to the Institution and commissioned Professor Tucker to bring it to the office of administration. A translation of this address is printed herewith:

> San Luis, *April 2, 1911.*
>
> The President of the Carnegie Institution,
> Dr. R. S. Woodward,
> *Washington, D. C., U. S. A.*
>
> The City of San Luis has been honored by the installation, at the foot of its mountains, of one of the historic telescopes of the world, for the purpose of recording a chapter in advanced science. The horizon of our pampa, parting its curtain of clouds, has freely allowed to be pictured the beautiful constellations of its sky.
>
> It is most gratifying to us to recognize the excellence of the work done at the Observatory of San Luis, and its great usefulness for the advancement of astronomy.
>
> The plan of Professor Boss of Albany, Director of the Department of Meridian Astrometry, has been executed with complete efficiency by the staff of the Observatory: Messrs. R. H. Tucker, A. J. Roy, W. B. Varnum, M. L. Zimmer, R. F. Sanford, P. T. Delavan, J. M. Fair, M. I. Roy, L. Z. Mearns, and H. Jenkins.
>
> The Carnegie Institution has in this manner linked the name of San Luis with posterity, and our people, thus distinguished, have expressed their spontaneous feelings towards Prof. R. H. Tucker, by offering him a gold medal and a public banquet on this occasion.
>
> The citizens of San Luis, with these sentiments, send their most cordial greetings to the honored President of that Institution, recognizing its noble mission of stimulating the cultivation of the Sciences which most honor the progress of humanity.

For reasons set forth in my report of a year ago, the construction of a vessel specially designed to meet the pressing needs of the Department of Marine Biology, at a cost of $25,000, was authorized by the Executive Committee at its meeting of October 18, 1910. Accordingly a bid of $15,000, from the Miami Yacht and Machine Company, of Miami, Florida, for the construction of the hull and upper works of such a vessel in conformity with designs carefully worked out by this company in collaboration with the Director of the Department, was accepted October 31, 1910. The equipment of the vessel, including engines, dredging, and other auxiliary apparatus, was supplied by the Director by purchase in open market at an aggregate cost of $10,000.

A description of this craft, along with a photographic illustration of her at sea, will be found in the annual report of the Director of the Department in the current Year Book. It may suffice here, therefore, to state that she is a 70-foot, twin-screw motor-boat, very staunchly built, and capable of cruising anywhere in the Gulf and adjacent tropical waters. An agreeable feature of the experience in the construction of this boat, in all respects similar to that met in the construction of the non-magnetic ship *Carnegie,* was the high professional standard sought by the designers and builders, Messrs. Peck and Lundblom, of the Miami Yacht and Machine Company. Every effort on their part was made to meet the requirements and to secure the highest efficiency. This new boat has been called the *Anton Dohrn,* in honor of the distinguished founder of the Stazione Zoologica, under whose direction, for more than thirty years, the Marine Laboratory at Naples has been one of the most fruitful international centers for biological research. In graceful recognition of this honor, Dr. Reinhard Dohrn, who has succeeded his father as Director of the Stazione Zoologica, has presented to the vessel an admirable bronze relief of Anton Dohrn, by Adolf Hildebrand.

A Retrospective View.

With the end of the current calendar year the Institution may be said to have completed the first decade of its history. This history is partly recorded, in a condensed form, in the Year Books, in the miscellaneous publications of the Institution, and in the printed but unpublished proceedings of the Board of Trustees and of the Executive Committee. A large part of this history is recorded only in the voluminous correspondence entailed by the productive work of the Institution, while no inconsiderable portion is filed in the more voluminous but tentative, unproductive, or fruitless correspondence incident to so novel an enterprise. The epoch for a comprehensive view of this history has not yet arrived. A decade is the smallest convenient unit of time by which the succession of events in such an establishment may be reckoned, and it will be essential to await the development of a series of units before just estimates may be drawn and adequate conclusions reached with respect to the early growth and the complex activities which have engrossed the attention and absorbed the income of the Institution during the first decade of its existence. On the other hand, without seeking to anticipate the verdict of our successors, or of our contemporaries, it appears appropriate at this time to recall in a summary way the salient facts of this history and to indicate in some instances the lessons which may be drawn from the extensive experience already acquired.

Looking backward from the end of the decade in question, the most striking fact in evidence appears to be the rapidity of early growth, although, paradoxical as it may seem, that growth has been disappointingly slow in meeting popular expectations and demands. The first formal meeting of the incorporators of the proposed institution was held January 4, 1902, and articles of incorporation in conformity with the laws of the District of Columbia were filed for record in the office of the Recorder of Deeds on the same day. The name designated for the establishment in the first of these articles of incorporation was Carnegie Institution. At this first meeting, also, twenty-seven Trustees were elected to administer the affairs of the Institution. Of this body five, namely, the President of the United States, the President of the Senate, the Speaker of the House of Representatives, the Secretary of the Smithsonian Institution, and the President of the National Academy of Sciences, were designated as ex-officio members. The first meeting of these Trustees was held January 29, 1902, when the Founder's deed of trust conveying the original endowment was received, when a code of by-laws was adopted, a formal organization under the title Board of Trustees effected, and the first President of the Institution elected. During the following year some questions arose as to the adequacy of the original act of incorporation under the laws of the District of Columbia, and at the stated meeting of the Board of Trustees held December 8, 1903, it was decided to apply to the Congress of the United States for a more comprehensive charter. Accordingly, new articles of incorporation were granted by the Fifty-eighth Congress in "An Act to Incorporate the Carnegie Institution of Washington," approved April 28, 1904. By the terms of these new articles the scope and limitations of the Institution are clearly defined, no members of the Board of Trustees are such ex officio, and the corporate title is changed from Carnegie Institution to Carnegie Institution of Washington. At a special meeting of the Board of Trustees held May 18, 1904, the formal steps essential to transition from the original to the present corporate organization were taken and ratified. At the stated meeting of the Board of Trustees held December 13, 1904, new by-laws, since unchanged except for minor amendments, were adopted. The first article of these by-laws specifies that "the Board of Trustees shall consist of twenty-four members, with power to increase its membership to not more than twenty-seven members, and that Trustees shall hold office continuously and not for a stated term."

In the meantime, while the foundations of organization were being laid, the Trustees, the Executive Committee, and numerous advisory committees were actively engaged in devising ways and means to carry out the comprehensive provisions of the trust. The amount of work of this kind accomplished during the first three years of the existence of the Institution appears truly surprising in view of the novelty of the enterprise and in view of the great diversity of expert opinion with respect to many fundamental, and to most subsidiary, questions which had to be considered. Special credit should be given in this connection to the unselfish labors of the advisory committees;

for, although their recommendations contemplated aggregate annual expenditures far in excess of available income, their deliberations helped in a signal manner to fix attention on practicable projects and on conditions essential to effective research. In the meantime, also, the actual expenditures under this income rose rapidly from (using round numbers) $32,000 in 1902 to $512,000 in 1904, reaching an amount of $702,000 in 1907, a maximum of $769,000 in 1909, and a total of $4,791,000 by the end of the year 1910. It is an interesting circumstance, likewise, worthy of special study at some later date, that along with this rapid growth of the work proper to the Institution there arose equally rapidly a wave of excessive popular expectations as to the possibilities of the new establishment, and especially as to the extent and the capacity of its income. No vagaries of fiction could surpass the realities of the unrealizable ideals and of the dreams of avarice developed in this wave, which culminated in 1905–6, and is only now slowly subsiding.

Three principal agencies to forward the objects of the Institution were developed early in the decade in question. The first of these involved the formation of departments of research, within the Institution itself, to attack larger problems requiring collaboration of several investigators, special equipment, and continuous effort. The second provides means whereby individuals may undertake and carry to completion investigations not less important but requiring less collaboration and less special equipment. The third agency—namely, a division devoted to the editing and printing of books—aims to provide adequate publication of the results of research coming from the first two agencies, and to a limited extent, also, for worthy works not likely to be published under other auspices. Ten of the larger departments of research referred to have been thus far established. These, in the order of their authorization as shown by the dates assigned, are the following:

Department of Experimental Evolution	December, 1903
Department of Marine Biology	December, 1903
Department of Historical Research	December, 1903
Department of Economics and Sociology	January, 1904
Department of Terrestrial Magnetism	April, 1904
Solar Observatory	December, 1904
Geophysical Laboratory	December, 1905
Department of Botanical Research	December, 1905
Nutrition Laboratory	December, 1906
Department of Meridian Astrometry	March, 1907

Along with these larger divisions of the research work proper, there may be not improperly classed, for the present purposes of historical summary, the divisions of administration and publication, for they also have made many researches in order to meet the requirements of their complex relations with the departments, with Research Associates, with collaborators, and with a host of correspondents. Originally evolved as part of the work of administration, the editorial and publication work grew to such necessary proportions that it was given a separate existence, under the title "Division of Publication," in July, 1909.

Of the work carried on by these departments and divisions and by the numerous Research Associates and collaborators, only a few statistical items may be indicated here. In a second edition, now in press, of a semi-popular pamphlet, issued on the occasion of the dedication of the Administration Building, in December, 1909, there may be found further historical details with respect to the organization, present status, and character of the work of the departments of research. In an appendix to the Year Book for 1911 there will be published, also, complete lists of the names of Trustees, members of departmental staffs, Research Associates, collaborators, and of all other persons hitherto connected with the Institution. From these lists it appears that upwards of fifteen hundred individuals have participated, during this first decade, in the work already accomplished or in that now under way. Summaries indicating the extent of the researches and of the publications of the Institution have been given in previous reports. Bringing these down to date, it may be said that a complete list of the fields of research to which contributions have already been made would include a plurality of the fields, ranging alphabetically from archeology and astronomy through law, linguistics, and literature up to thermodynamics and zoology. In answer to the perennial question, raised by a multitude of correspondents, why other fields have not been likewise entered, it seems fitting to remark here that this fact is due neither to lack of interest on the part of the Institution in these other fields nor to neglect on the part of the public in pressing their importance, but to the more obvious reasons arising from the limitations of income, time, and accessibility. Researches of one kind or another under the auspices of the Institution have been carried on in nearly every country, and the publications already issued have been placed in nearly all of the leading libraries of the world, and especially in those of colleges and universities. Up to date these publications have been issued under 156 different titles and in 201 separate volumes. A total of 90,730 volumes has thus far been distributed, chiefly by gifts to libraries and to authors, but to a noteworthy extent also by sales to the increasing number of individuals and institutions preferring to acquire books by purchase. In addition to these works which have been published by the Institution itself, about fifteen hundred papers, giving results of investigations made under its direct or indirect auspices, have appeared in current journals, in proceedings of societies, and other contemporary media. For the larger undertakings in research, two astronomical observatories, five laboratories, and a non-magnetic ship have been built and equipped, and a total inventory of property under this head includes sixty buildings, ten vessels, and thirteen parcels of land. A considerable aggregate of property in apparatus and equipment has been provided, also, by grants to individual investigators, who are connected mostly with colleges and universities. The total of expenditures of the Institution to daté is $5,452,687.21. Of this amount, $1,682,437.53 are represented in land, buildings, equipments, and publications in stock; $416,978.39 have paid the costs of administration and miscellaneous expenses incident thereto; $318,804.13 have been spent in the work of publications; and $4,008,540.38 have been applied directly to the prosecution of research.

The rapid march of events in the early life of the Institution and the relatively small part an individual can play in the aggregate of its history are emphasized especially by an impressive death-roll of members of the Boards of Trustees in the original and in the present corporation. Of a total of forty-three individuals in these two boards, thirteen are deceased, including the Chairman of the first Board of Trustees, Abram S. Hewitt, and the first President of the Institution, Daniel C. Gilman. But these colleagues were all as ripe in years as in usefulness, and the recollection of their devotion to the interests of the Institution may serve to give zeal and confidence to their successors in a continuity of endeavor "to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind."

Financial Statement for Fiscal Year 1910-1911.

The sources of funds available for expenditure during the past fiscal year, the allotments for the year, the revertments made during the year, and the balances unallotted at the end of the year are shown in detail in the following statement:

Object of appropriation.	Unallotted Oct. 31, 1910.	Appropriation, Dec. 13, 1910.	Revertments Oct. 31, 1910, to Oct. 31, 1911.	Total.	Aggregates of allotments and amounts transferred.	Balances unallotted Oct. 31, 1911.
Large grants.....	....	$482,797.00	$10,000.00	$492,797.00	$492,797.00	....
Minor grants.....	....	97,124.03	2,190.10	99,314.13	94,314.13	$5,000.00
Research associates and assistants	....	24,200.00	....	24,200.00	24,200.00	....
Publications	$7,620.16	60,000.00	3,712.07	71,332.23	56,007.90	15,324.33
Administration...	14,553.80	45,000.00	6,463.22	66,017.02	45,455.80	20,561.22
Total......	22,173.96	709,121.03	22,365.39	753,660.38	712,774.83	40,885.55

The following list shows the departments of investigation to which the larger grants were made by the Trustees at their last annual meeting and the amounts allotted from these grants by the Executive Committee during the year:

Department of Botanical Research..........................	$36,680
Department of Economics and Sociology.....................	10,000
Department of Experimental Evolution......................	33,734
Geophysical Laboratory	54,480
Department of Historical Research..........................	23,500
Department of Marine Biology..............................	32,980
Department of Meridian Astrometry........................	31,480
Nutrition Laboratory	30,378
Division of Publication..	9,000
Solar Observatory	136,055
Department of Terrestrial Magnetism......................	94,510
	492,797

The fields of investigation to which minor grants were assigned, the names of the grantees, and the amounts of the grants are shown in the following list:

Details of minor grants.

Field of investigation.	Names of grantees.	Amount of grants.
Archeology	Bandelier, Adolf F	$2,000.00
Bibliography	Index Medicus	12,500.00
Chemistry	Bancroft, W. D	1,500.00
	Acree, S. F	1,500.00
	Baxter, G. P	1,000.00
	Osborne, T. B	8,000.00
	Jones, H. C	1,000.00
Geophysics	Adams, F. D	800.00
History	Osgood, H. L	500.00
Literature	Sommer, H. Oskar	2,000.00
Mathematics	Morley, Frank	1,200.00
Meteorology	Bjerknes, V	1,800.00
Paleontology	Wieland, G. R	200.00
Physics	Howe, Henry M	500.00
	Barus, Carl	500.00
	Nichols, E. L	3,000.00
Physiology	Cathcart, E. P	1,000.00
	Reichert, E. T	1,500.00
Political Science	Rowe, Leo S	1,500.00
Zoology	Castle, W. E	1,000.00
	Naples Zoological Station	1,000.00
		44,000.00
Transferred	Large grants	1,000.00
	Administration	3,600.50
	Unappropriated fund	45,713.63
		94,314.13

The following table shows the fields of investigation of research associates and the amounts of their grants:

Field of investigation.	Names of research associates.	Amount of grants.
Astronomy	Kapteyn, J. C	$2,000.00
	Gale, Henry G	1,000.00
Archeology	American School of Classical Studies in Rome	2,000.00
	Van Deman, E. B	1,200.00
Botany	Huntington, Ellsworth	1,500.00
Chemistry	Richards, Theodore W	2,500.00
	Morse, H. N	1,800.00
	Jones, Harry C	1,200.00
	Noyes, A. A	3,000.00
Geology	Chamberlin, T. C	4,000.00
	Moulton, F. R	2,000.00
Paleography	Loew, Elias A	1,500.00
		23,700.00
Transferred to unappropriated fund		500.00
		24,200.00

The following grants for publication were authorized during the year:

American Ethnological Society	$900.00
Barus, Carl	800.00
Baxter, G. P.	307.82
Benedict, F. G., and E. P. Slack	550.00
Bjerknes, V.	2,900.00
Bolton, H. E.	1,600.00
Campbell, D. H.	308.90
Case, E. C.	3,000.00
Case, E. C.	2,000.00
Castle, W. E., and J. C. Phillips	250.00
Churchill, William	348.20
Churchill, William	300.00
Day, A. L., and R. B. Sosman	1,000.00
Decker, Floyd F.	159.33
Howard, L. O.	5,000.00
Jones, H. C., and W. W. Strong	2,600.00
King, Arthur S.	600.00
Learned, M. D.	1,500.00
Lehmer, D. N.	$2,350.00
Mark, E. L., and J. A. Long	43.12
Mayer, A. G.	1,400.00
Moulton, F. R.	4,500.00
Nichols, E. L., and E. Merritt	2,000.00
Osborne, T. B., and L. B. Mendel	600.00
Osborne, T. B., and L. B. Mendel	850.00
Papers from the Tortugas Laboratory	740.53
Parker, D. W.	1,800.00
Republication of the Classics of International Law	10,000.00
Russell, H. N.	1,600.00
Sommer, H. O.	3,000.00
Stager, H. W.	1,600.00
Wright, F. E.	1,400.00
Total	56,007.90

The sources and amounts of the revertments from November 1, 1910, to October 31, 1911, inclusive, are shown in the following list:

Large grants:			
Transferred from Insurance		$4,000.00	
Transferred from Insurance		5,000.00	
Transferred from Minor grants		1,000.00	
			$10,000.00
Minor grants:			
Goss, W. F. M., Grant No. 425		94.73	
Carhart, H. S., Grant No. 151		95.37	
Smith, Edgar F., Grant No. 588		2,000.00	
			2,190.10
Publication:			
Bjerknes and Sandström, Grant No. 466		247.14	
Goss, W. F. M., Grant No. 642		576.34	
Benedict and Joslin, Grant No. 655		133.24	
MacDougal and Spalding, Grant No. 662		50.30	
Papers from Tortugas Laboratory, Grant No. 654		97.57	
Jones and Strong, Grant No. 653		411.57	
Lutz, F. E., Grant No. 666		10.96	
Adams, W. S., Grant No. 657		122.24	
Allison, W. H., Grant No. 656		68.63	
Fish, C. R., Grant No. 644		371.40	
Castle and Phillips, Grant No. 670		62.14	
Cannon, W. A., Grant No. 651		553.17	
Lloyd, F. E., Grant No. 660		352.23	
Osborne and Mendel, Grant No. 714		261.22	
Churchill, William, Grant No. 721		65.19	
Parker, D. W., Grant No. 671		5.94	
Barus, Carl, Grant No. 713		322.79	
			3,712.07
Administration:			
Shipping expenses (25 per cent sales of publications)	$2,723.06		
Shipping expenses (reprints from Solar Observatory)	102.71		
Shipping expenses (expressage)	1.57		
		2,827.34	
Refund, express charges		3.35	
Refund, light and telephone		29.53	
Refund, office petty expenses		2.50	
Transferred from Minor grants		3,600.50	
			6,463.22
			22,365.39

Summary of Receipts and Expenditures of the Institution to Date.

The aggregate receipts from interest on endowment, from interest on bond investments, from interest on deposits in banks, from sales of publications, from refund on grants, and miscellaneous items to date is $5,929.390.37, as shown by the following table:

Year ending Oct. 31—	Interest.		Sales of publications.	Refund on grants.	Miscellaneous items.	Total.
	Endowment.	Bonds and bank deposits.				
1902.......	$250,000.00	$9.70	....	....	$1,825.52	$251,835.22
1903.......	500,000.00	5,867.10	$2,286.16	....	101.57	508,254.83
1904.......	500,000.00	33,004.26	2,436.07	$999.03	....	536,439.36
1905.......	500,000.00	25,698.59	3,038.95	200.94	150.00	529,088.48
1906.......	500,000.00	27,304.47	4,349.68	2,395.25	19.44	534,068.84
1907.......	500,000.00	22,934.05	6,026.10	2,708.56	15.22	531,683.93
1908.......	550,000.00	17,761.55	7,877.51	25.68	48,034.14	623,698.88
1909.	600,000.00	14,707.67	11,182.07	2,351.48	103,564.92	731,806.14
1910.......	600,000.00	10,422.78	10,470.25	1,319.29	54,732.45	676,944.77
1911.......	975,000 00	14,517.63	10,892.26	4,236.87	923.16	1,005,569.92
	5,475,000.00	172,227.80	58,559.05	14,237.10	*209,366.42	5,929,390.37

* Of this amount, $200,250 were received from the sale of bonds in 1908, 1909, and 1910.

The purposes for which funds have been appropriated by the Board of Trustees of the Institution may be summarily classified under five heads, namely: (1) investments in bonds and on account of Administration Building; (2) large projects; (3) minor projects, special projects, and research associates and assistants; (4) publications; (5) administration. The actual expenditures under these heads for each year since the foundation of the Institution are shown in the following table:

Year ending Oct. 31—	Investments in bonds and on account of Administration Building.	Large projects.	Minor projects, special projects, research associates and assistants.	Publications.	Administration.	Total.
1902.....	....	....	$4,500.00	....	$27,513.00	$32,013.00
1903.....	$100,475.00	....	137,564.17	$938.53	43,627.66	282,605.36
1904.....	196,159.72	$49,848.46	217,383.73	11,590.82	36,967.15	511,949.88
1905....	51,937.50	269,940.79	149,843.55	21,822.97	37,208.92	530,753.73
1906.....	63,015.09	381,972.37	93,176.26	42,431.19	42,621.89	623,216.80
1907.....	2,000.00	500,548.58	90,176.14	63,804.42	46,005.25	702,534.39
1908.....	68,209.80	448,404.65	61,282.11	49,991.55	48,274.90	676,163.01
1909.....	116,756.26	495,021.30	70,813.69	41,577.48	45,292.21	769,460.94
1910.....	57,889.15	437,941.40	73,464.63	49,067.00	44,011.61	662,373.79
1911.....	51,921.79	463,609.75	63,048.80	37,580.17	45,455.80	661,616.31
Total..	708,364.31	3,047,287.30	961,253.08	318,804.13	416,978.39	5,452,687.21

Investments in Property.

On account of site for and construction of the Administration Building of the Institution, and on account of real estate, buildings, and equipments of departmental establishments, the following sums have been expended:

Administration:		
Building, site, and equipment		$319,220.67
Publications:		
Stock on hand and outstanding accounts (Oct. 31, 1911)		186,639.28
Department of Botanical Research (Sept. 30, 1911):		
Buildings, office, and operating appliances	$34,634.02	
Laboratory equipment	7,259.53	
		41,893.55
Department of Experimental Evolution (Sept. 30, 1911):		
Buildings, office, and library	39,887.04	
Laboratory apparatus	4,527.02	
Operating appliances and grounds	16,000.68	
		60,414.74
Geophysical Laboratory (Sept. 30, 1911):		
Building, library, operating appliances	113,310.81	
Laboratory apparatus	60,361.47	
Shop equipment	10,742.20	
		184,414.48
Department of Marine Biology (Sept. 30, 1911):		
Vessels	31,674.95	
Buildings, docks, furniture, and library	10,055.88	
Apparatus and instruments	2,515.82	
		44,246.65
Department of Meridian Astrometry (July 31, 1911):		
Buildings and operating appliances	13,518.90	
Apparatus and instruments	2,394.34	
		15,913.24
Nutrition Laboratory (Sept. 30, 1911):		
Building and office	109,591.73	
Laboratory apparatus	10,893.89	
Shop equipment	1,923.33	
		122,408.95
Solar Observatory (Aug. 31, 1911):		
Building, grounds, road, and telephone line	120,464.79	
Shop equipment	19,304.65	
Instruments	315,463.67	
Furniture and operative appliances	50,746.90	
Hooker 100-inch reflector	49,965.91	
		555,945.92
Department of Terrestrial Magnetism (Sept. 30, 1911):		
Office	4,697.42	
Instruments	25,214.13	
Vessel and ocean equipment	117,019.48	
Land equipment	4,409.02	
		151,340.05
		1,682,437.53

RÉSUMÉ OF INVESTIGATIONS OF THE YEAR.

Status of Departments of Research.

The past fiscal year has been, on the whole, the most fruitful year on record for the ten specially organized departments of research in the Institution. Although some of these are not yet fully equipped, they are all so well organized and provided for that their energies may now be chiefly directed to the attainment of definite results.

A development of much interest in connection with these departments is that of cooperative effort coming through Research Associates and collaborators. The departmental facilities are already in considerable demand from capable investigators, and many of them are found desirous of using these facilities, not only to forward their own researches, but to collaborate in the researches proper of the departments. The favorable experience which has accrued in recent years in these matters indicates that it may be advantageous in the future to seek to secure an additional number of investigators who, by reason of their eminence, may collaborate effectively in this manner.

Each of these departments has now under way such a variety and complexity of work that it is difficult to summarize. Reference must be made, therefore, for matters of detail, to the reports of the directors of the departments, published in full in the current Year Book. Hence such allusions in the following paragraphs as are made to the progress of the year are necessarily brief and can deal only with the more salient aspects of departmental affairs and researches.

Department of Botanical Research.

The activities of this department now necessarily cover a wide range, since any successful attempt to solve the problems of the origin, development, migration, and modification under varying climatic conditions of plant life must require extensive field observations, much laboratory experimentation, and increasing application of the sciences of chemistry and physics. It is natural and proper, therefore, that the staff and collaborators of the department should include many specialists, and that they should approach the problems to be investigated from many points of view. Thus it happens that the investigations of the past year have embraced, among others, studies of the evaporation, the increasing salinity, and the changes in vegetation following close after the receding shores of the Salton Sea; of the influences of temperature, rainfall, sunlight, soil-moisture, etc., on plant organisms; of the effects following transplantation from low to high altitudes and from arid to humid localities; of the variations in water and acid content of plants; of the chemical effects induced in plant tissue by light and heat; and of the physiological functions of leaves in plant life.

One of the most interesting investigations under way during the year is that of Dr. Ellsworth Huntington, Research Associate of the department, on the secular variations of climate of the southwest desert area in recent geologic time. From this work it is believed that some of the salient fluctuations in climate during the past two or three thousand years may be clearly made out. Another noteworthy investigation of the year is that of the respiration of cacti, undertaken by Prof. H. M. Richards in collaboration with the department. This has developed the remarkable fact of a definite diurnal periodicity in the acid content of the sap of the cacti under observation. The progress and status of many other instructive investigations are set forth at length under the twenty subdivisions of the Director's report, to be found in full in the current Year Book. From this it appears that, in addition to the regular and associate members of the staff of the department, about an equal number of individual investigators have collaborated in the researches under way. Special attention may be here invited to the detailed account given in one of the subdivisions of this report by Professor Tower in reference to his further experiments on the evolution of chrysomelid beetles, the results of his early work in this line under the auspices of the Institution having been issued as publication No. 48.

Department of Experimental Evolution.

It is a well-known fact that important generalizations in science usually leave a multitude of details to be worked out. Indeed, advances often raise more questions than they settle. Such has been the wonderfully fruitful effect of the doctrine of evolution propounded by Darwin, Spencer, and Wallace a half century ago. It should not be surprising, therefore, that the program of the Department of Experimental Evolution presents a considerable variety of investigations related to the highly complex problem of heredity chosen by the Director as the principal object of research. Thus the work of the year includes investigations of heredity in plants, insects, birds, animals, and man.

One of the most promising investigations of the year is that of the Director in reference to the heredity of epileptics. Through his connection with the Eugenics Record Office, he has collaborated with Dr. David F. Weeks, of the New Jersey State Village of Epileptics, and secured a large quantity of accurate statistical data bearing directly on this disorder. From these data it appears not improbable that important practical deductions may be presently, if not already, drawn. Another investigation continued during the year, which involves prime utilitarian application, is that of Dr. Shull on the effects of self-fertilization in maize, or Indian corn. His earlier conclusions, published in 1908, have been confirmed by the later studies. A striking result from the latter is that, other conditions being the same, the yield of cross-fertilized plants proved fifty per cent greater than that of the self-fertilized plants. Observational and experimental work has been carried on also along many other lines. The total number of zoological individuals under study exceeded 2,000, while the range of plants observed included nearly 500 species and upwards of 40,000 individuals.

Department of Economics and Sociology.

The diversified work of this department has proceeded during the year in accordance with the plan approved by the Executive Committee in May, 1910, which contemplated completing the researches then under way as well as might prove practicable under the limitations of the balance of appropriations previously made to the department. A full statement of these appropriations, of the expenditures under them to date, and of the present available balance, will be found in the section of this report devoted to the proposed budget for the ensuing year.

As explained at length by the Chairman of the department in his report, to be found in the current Year Book, progress in the work under way is necessarily slow, since the heads of the divisions of research and most of their collaborators are primarily engaged in other occupations. But in spite of this handicap, inherent in the organization, much work has been accomplished, and the Chairman reports that several of the heads of divisions are now engaged on their final reports.

Department of Historical Research.

The eighth annual report of this department, and the sixth of the present Director, is an instructive record of effective progress along all lines of work thus far undertaken to discover and to render available the sources of American history. Members of the department have been engaged during the year searching the archives of Great Britain, France, Spain, and Mexico, as well as those of the United States, for all accessible data, and these are being rapidly put in form for publication in convenient manuals. Three such works have been published by the Institution during the past year, namely, "Guide to the Materials for American History in Roman and other Italian Archives"; "Inventory of Unpublished Material for American Religious History in Protestant Church Archives and other Repositories"; and "Calendar of Papers in Washington Archives relating to the Territories of the United States." The following are now in press: "Guide to the Manuscript Material relating to American History in the German State Archives" and "Guide to Materials for the History of the United States in the Principal Archives of Mexico."

It is worthy of remark that the results of this department's activities have received very general commendation from professional historians in Europe as well as in America. The ten manuals thus far issued are already much in demand in foreign countries, and they seem destined to become as important in aggregate usefulness abroad as at home. It is hoped that the Institution may be thus enabled to render adequate acknowledgment for numerous courtesies extended to the department by officials of governments, archives, libraries, and other establishments.

Geophysical Laboratory.

The signal success already attained by this laboratory leaves no reason for doubt as to the practicability of continued advances toward solution of that large and difficult group of chemical and physical problems presented by the materials of the earth's crust. The current report of the Director reviews twenty-six papers which have been issued by members of the staff of the laboratory during the year. Among these papers is a noteworthy contribution to general physics, in which the scale of precise thermometry is extended by 1250° C. This extension was an essential incident to the studies of mineral fusion, crystallization, etc., carried on in the laboratory, but it is of equal importance to other branches of physical research. Another noteworthy paper is a preliminary contribution to the long-standing question of the constitution of Portland cement. The complexity of this substance proves to be far greater than hitherto supposed; but its general characteristics have been determined and the resources of the laboratory are adequate to complete the remaining quantitative details of the investigation.

International appreciation of the work of the Institution is now shown in many ways. The merits of the researches of the Geophysical Laboratory have been more promptly recognized, indeed, than its projectors anticipated. Thus nearly all of the preliminary papers issued by members of the staff of the laboratory have been published in German as well as in English, and arrangements have been made during the past year to have all such papers appear contemporaneously in both of these languages.

Of numerous investigations under way at the laboratory, attention may be called here to some preliminary studies of an active volcano, which indicate that the phenomena of vulcanism are within range of practicable determination and that progress in this direction is only a question of time and adequate effort.

Department of Marine Biology.

In addition to the research work proper carried on by the Director of this department during the year, much of his time and attention have been devoted to the construction of a new vessel and to the reconstruction of the laboratory at Dry Tortugas. Referenne to this vessel, named the *Anton Dohrn*, has been made in a previous section of this report, and a description of her characteristics and equipment will be found in the current report of the Director. It may suffice here, therefore, to state that this adjunct gives the department independent and adequate transportation facilities and greatly enlarged opportunities for marine research.

Mention was made in my report of a year ago of the probable damage done to the Tortugas Laboratory by the destructive hurricane which swept the Florida Keys October 17, 1910. An inventory of the wreckage was made as soon as practicable, and it was found that an expenditure of $4,000 would be essential to renew the establishment in a safe and effective manner. Accordingly, an allotment of this amount from the insurance fund of the Institution was made by the Executive Committee at its meeting of November 17, 1910, and the wrecked buildings have been replaced during the past summer by structures at once more secure and more commodious.

On account of lack of quarters the Director has been able to afford facilities for research at the laboratory to only eight investigators. Nevertheless, the year has proved fruitful in important advances. One of these, attained by Mr. G. H. Drew, of Cambridge University, relates to the rôle of certain bacteria in depriving surface sea water of nitrogen and in precipitating the vast deposits of chalky mud (oolite) of the Florida-Bahama region; another, by Dr. T. W. Vaughan, records definite progress in his quantitative determinations of the growth of corals and coral reefs; while the Director and his collaborators have published twenty-one papers, mostly included in volumes Nos. 132 and 133 of the publications of the Institution.

Department of Meridian Astrometry.

As already explained in a preceding section of this report, the meridian determinations of stellar positions at the temporary observatory at San Luis, Argentina, were finished in January, 1911. This completion in an unexpectedly short time of the more formidable part of the undertaking of the department in the southern hemisphere leaves only the minor task in photometry of measuring the magnitudes (or brightness) of those stars for which this property has not been hitherto measured. This task, requiring only two observers and light equipment, will be subject to small expense.

In the meantime the deductions of stellar positions and motions are proceeding expeditiously in the computing section of the department at the Dudley Observatory; so that the final catalogue, giving precise positions of all stars up to the seventh magnitude inclusive, may be expected to appear in due time. As often happens in such extensive scientific investigations, many by-products are arising of hardly less importance than the primary ends in view. One of these, deduced from the Director's preliminary Star Catalogue, published by the Institution about two years ago, shows the mean velocities relative to the solar system of stars of different spectral types. The values derived from the "proper motions" of the catalogue are in striking agreement with those derived for the same stars by Prof. W. W. Campbell from direct measurements of the motions of these stars in the line of sight. The remarkable result which is thus brought out from independent investigations is that the speed of a star through space increases with its age. Attention is here invited to the Director's interesting summary of this by-product in his current report, the investigation in full having been published in the Astronomical Journal, April 3, 1911. It is of interest to note in this connection that the independent investigations of Campbell, referred to above, were also carried out by aid of grants made by the Institution.

Nutrition Laboratory.

Allusion has been made frequently in previous reports to a prime characteristic in the progress of all of the more highly developed sciences. This consists in the passage from the stage of observation and experiment to the stage of measurement and calculation, or in the transition from the stage of qualitative to that of quantitative knowledge. It is marked by the introduction of the meter, the balance, the thermometer, the telescope, the microscope, etc., and the definite methods of chemistry and physics. The development of the work of the Nutrition Laboratory affords a capital illustration of this characteristic mode of procedure, and therein we find also the best justification for confidence in the enterprise.

The staff of the laboratory has been occupied during the year in the construction of new apparatus, in the improvement of apparatus already in use, in numerous researches on pathological and normal subjects, and in the preparation and publication of reports on results already attained. The year has shown also a remarkable increase of interest in the work of the establishment coming especially from members of the medical profession at home and abroad. Several of these have collaborated very effectively in the experiments under way, and the widely general approval of the objects and methods of the laboratory insures the heartiest cooperation from experts in the closely allied fields of physiological and pathological research.

The numerous investigations in progress and the publications issued during the year are reviewed in interesting detail in the Director's report. Of the nine publications issued, one (No. 155 of the Institution) gives the results of an important study of the variations of temperature in different parts of the human body. Of equal popular and technical interest also are the results, recorded in another paper, of experiments on men to determine the effects of breathing air rich in oxygen content.

The Solar Observatory.

By reason of the absence on leave of Professor Hale, the varied work of this Observatory has been in general charge of Mr. Walter S. Adams, who, as Acting Director, has prepared the report of progress for the past fiscal year as well as that for the year 1909-1910. Quite fortunately the affairs of the Observatory have proceeded without serious delay during Professor Hale's absence, and it is gratifying to announce that his health was so far restored as to permit him to return to his duties October 1, 1911.

Although the construction and equipment of the Observatory are still incomplete, the members of the staff are making rapid progress with their programs of solar, stellar, and physical observation and of computation and deduction. Thus the attainment of tangible results proceeds along with the development and installation of equipment. Attention is invited to a list of such results, attained during the year, cited in interesting detail by Mr. Adams in his report, but too long for an abstract in this place. It need only be said of them here that they justify expectations and that they increase confidence in the capacity of the establishment to advance astrophysical science.

The Observatory has now, nearly fully equipped and in use, four highly effective telescopes: the Snow, horizontal, 30-inch reflector; the two tower-telescope refractors; and the 60-inch reflector mounted equatorially. The 150-foot tower telescope, together with its auxiliary apparatus, constitutes the most important addition of the year in the way of equipment. Varied use of the 60-inch equatorial proves it to be alike effective in visual, photographic, and spectroscopic work. It is especially penetrating in its capacity to reveal the characteristics of globular star clusters and spiral nebulæ.

In view of the repeated failures of the contractors of St. Gobain, France, to cast a perfect disk for the 100-inch "Hooker telescope," it was determined to try the imperfect disk furnished by these contractors, but not accepted, four years ago. Accordingly an agreement was entered into with the makers to try shaping the disk, and to pay therefor in case it proves sufficiently stable after adequate trial. This work was begun early in the year, and good progress has already been made, although some delay must result by reason of the illness of Professor Ritchey and his chief assistant in this delicate and laborious task. In the meantime the glass-founders of St. Gobain are unremitting in their efforts to secure a perfect disk.

It is with deep regret that the Observatory and the Institution are called upon to record the unexpected death, on May 24, 1911, of Mr. John Daggett Hooker, to whom the enterprise of the 100-inch telescope owes its inception. His intelligent interest in and appreciation of the work of the Mount Wilson Solar Observatory led him to make a gift of $50,000 in 1906 for the purchase of a disk and for the shaping of it for a 100-inch reflecting telescope. Unfortunately the difficulties in the way of casting so large a disk of glass, together with his untimely death, have prevented him from realizing his desire to see this telescope in use. But if the enterprise succeeds, as now seems quite hopefully probable, the Observatory and the Institution will be glad to link the constancy of his faith in scientific investigation to the constancy of the stars by means of diligent applications of the "Hooker telescope" to astronomical research.

Department of Terrestrial Magnetism.

The magnetic survey of the globe undertaken by this department is proceeding effectively on both land and sea. Observations of the magnetic elements of declination, dip, and intensity have been made at numerous points on the continents of Asia, Africa, Australia, Europe, South America, and on the Polynesian Islands; while the non-magnetic ship *Carnegie* has secured a large quantity of data of immediate practical utility to navigation and of still greater importance, doubtless, in their relations to the general problem of terrestrial physics.

At the end of the previous fiscal year the *Carnegie* was en route from the mouth of the Amazon to Rio de Janeiro. After visiting the ports of Rio de Janeiro, Montevideo, Buenos Aires, and Cape Town, she arrived at Colombo, Ceylon, June 7, 1911. Having started on her present circumnavigation cruise June 20, 1910, her arrival at Colombo marked the end, approximately, of the first year out. During this year she traversed upwards of 23,000 nautical miles, measuring magnetic declinations at 252 different points, and dip and intensity at 172 different points at sea. In addition to this work, corresponding complete determinations were made on land at seven ports and intercomparisons of magnetic instruments were made at three ports.

Unexpectedly large errors have been found almost everywhere, except in the South Atlantic Ocean, in the best compass sailing charts now in use. This is especially the case in the Indian Ocean, for which some recently issued charts are in error as much as 4° to 6° in the "compass variations" assigned. To meet the pressing needs of mariners for more trustworthy charts, the data obtained by the *Carnegie* are promptly furnished to the hydrographic establishments of the world engaged in the publication of magnetic charts. It appears from the investigations of the department that the chief source of the errors in existing charts lies in a lack of knowledge of the secular variation of the magnetic elements. It is worthy of note, also, in this connection that observations of atmospheric electricity and atmospheric refraction have been carried on during this voyage of the *Carnegie*. The importance of precise navigation in recent times gives special interest to the outstanding uncertainties due to atmospheric refraction.

Expeditions for land determinations of magnetic data have been made to many countries and to many islands. The most extended of these are that carried out by Mr. Stewart in traversing the length of the Amazon River and that by Mr. Sligh in Asia Minor, Turkey, Arabia, Greece, Tripoli, Tunis, and Algeria. The Director of the department, on his way to meet the *Carnegie* at Colombo, made observations at Tau Island, of the Samoan Group, on the day of the total solar eclipse, April 28, 1911; and also at six other island stations in the course of his voyage.

The office work of computation and compilation of results and of the construction and testing of instruments has proceeded simultaneously with the operations on land and sea. A complete collection of the data obtained since the establishment of the department, including those of the cruises of the *Galilee* and *Carnegie,* will be ready for publication by the end of the present calendar year. Three portable magnetometers have been completed and four others are under construction, while various improvements to instruments and apparatus in use have been made, along with all current repairs, in the construction and repair shop of the department.

Investigations of Research Associates.

Between fifty and sixty Research Associates have carried on investigations under the auspices of the Institution during the year, either by aid of grants made directly to them or for the purpose of publishing results of their investigations. Several of these Associates have been connected with the departments of investigation. Many collaborators have also participated in the researches carried on under this head, and the fields of investigation are numerous and of very diverse kinds. An idea of the extent and variety of this work can be best gained by consulting the reports, in the current Year Book, of the individual investigators, by reference to the annual list of publications of the Institution, and the general bibliography of the year. As indicating the diversity of these investigations, attention may be called to two remarkable publications in widely different fields. One of these is a treatise on Dynamic Meteorology and Hydrography, by Prof. V. Bjerknes, of the University of Christiania, and marks a noteworthy advance in this difficult branch of mathematical physics. Part I of this work has been issued and Part II is now in press. It is interesting to note, also, that permission has been given to a foreign publishing house to bring out an edition of this work in the German language. The other work referred to is entitled "The Polynesian Wanderings," by Mr. William Churchill. It attempts to trace the migrations of the Polynesians in the Pacific Ocean by means of a critical examination of the philological contents of their language. Mention may also be made in this connection of progress in the publication of the Classics of International Law, one work of which—namely, that of Richard Zouche—having been completed.

PUBLICATIONS.

Publications Authorized and Issued during the Year.

The publication of twenty-five volumes* has been authorized by the Executive Committee during the year at an aggregate estimated cost of $44,100. The following list gives the titles and names of the authors of the publications issued during the year. It includes 30 volumes, with an aggregate of 5,062 octavo pages and 1,670 quarto pages.

List of Publications issued during the year.

Year Book No. 9, 1910. Octavo, XVI + 258 pages, 5 plates.
Index Medicus, Second Series, vol. 8, 1910. Octavo, 1420 pages.
No. 27. Smith, Erwin F. Bacteria in Relation to Plant Diseases. Vol. II. History, General Considerations, Vascular Diseases. Quarto, VIII + 368 pages, 20 plates, 148 text figures.
No. 74. Sommer, H. Oskar. Vulgate Version of the Arthurian Romances. Edited from MSS. in the British Museum. Quarto. Vol. IV. Le Livre de Lancelot de Lac, Part II, 399 pages.
No. 88. Bjerknes, V., and J. W. Sandström. Dynamic Meteorology and Hydrography. Part I, Statics. Quarto, 146 + *1a–36a, 1b–30b,* and *1c–22c* pages.

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* A list of these volumes is given in the financial statement on page 16.

No. 120. Decker, Floyd F. The Symmetric Function Tables of the Fifteenthic. Quarto, 21 pages.

No. 127. Goss, W. F. M. Superheated Steam in Locomotive Service. Octavo, v + 144 pages, 6 plates, 88 text figures.

No. 128. Fish, C. R. Guide to the Materials for American History in Roman and other Italian Archives. Octavo, ix + 259 pages.

No. 130. Jones, Harry C., and W. W. Strong. A Study of the Absorption Spectra of Solutions of Certain Salts of Potassium, Cobalt, Nickel, Copper, Chromium, Erbium, Praseodymium, Neodymium, and Uranium, as affected by Chemical Agents and by Temperature. Octavo, ix + 159 pages, 98 plates. (See Publications Nos. 60, 80, 110, and 160.)

No. 131. Cannon, William A. The Root Habits of Desert Plants. Octavo, 96 pages, 23 plates, 17 text figures.

No. 132. Papers from the Tortugas Laboratory of the Carnegie Institution of Washington. Octavo, 152 pages, 37 text figures, 18 plates.

No. 133. Papers from the Tortugas Laboratory of the Carnegie Institution of Washington. Octavo, iii + 185 pages, 17 text figures, 43 plates.

No. 134. Churchill, William. The Polynesian Wanderings: Tracks of the Migration deduced from an Examination of the Proto-Samoan Content of Efaté and other Languages of Melanesia. Octavo, viii + 516 pages, 2 plates.

No. 137. Allison, William H. Inventory of Unpublished Material for American Religious History in Protestant Church Archives and other Repositories. Octavo, vii + 254 pages.

No. 138. Adams, Walter S., assisted by Jennie B. Lasby. An Investigation of the Rotation Period of the Sun by Spectroscopic Methods. Quarto, iii + 132 pages, 2 plates, 5 text figures.

No. 139. Lloyd, Francis E. Guayule: A Rubber Plant of the Chihuahuan Desert. Octavo, viii + 213 pages, 46 plates, 20 text figures.

No. 140. Campbell, Douglas H. The Eusporangiatæ: The Comparative Morphology of the Ophioglossaceæ and Marattiaceæ. Quarto, vi + 229 pages, 13 plates, 192 text figures.

No. 141. MacDougal, D. T., and E. S. Spalding. Water Balance of Succulent Plants. Octavo, iv + 77 pages, 8 plates, 16 text figures.

No. 142. Long, J. A., and E. L. Mark. The Maturation of the Egg of the Mouse. Octavo, iv + 72 pages, 7 plates, 7 text figures.

No. 143. Lutz, Frank E. Experiments with Drosophila ampelophila, concerning Evolution. (Paper No. 16, Station for Experimental Evolution.) Octavo, iii + 40 pages, 53 text figures.

No. 144. Castle, W. E., and J. C. Phillips. On Germinal Transplantation in Vertebrates. (Paper No. 17, Station for Experimental Evolution.) Octavo, 26 pp., 2 pl.

No. 145. Case, E. C. A Revision of the Cotylosauria of North America. Quarto, 122 pages, 14 plates, 52 text figures.

No. 147. Russell, Henry Norris. Determinations of Stellar Parallax, based upon photographs taken at the Cambridge Observatory by Arthur R. Hinks and the writer; with Magnitudes and Spectra determined at the Harvard College Observatory under the direction of Prof. E. C. Pickering. Quarto, vi + 142 pages.

No. 148. Parker, David W. Calendar of Papers in Washington Archives relating to the Territories of the United States. Octavo, 476 pages.

No. 149. Barus, Carl. The Production of Elliptic Interferences in Relation to Interferometry. Octavo, vi + 77 pages, 33 text figures.

No. 154. Churchill, William. Beach-la-mar: The Jargon or Trade Speech of the Western Pacific. Octavo, 54 pages.

No. 155. Benedict, Francis G., and Edgar P. Slack. A Comparative Study of Temperature Fluctuations in Different Parts of the Human Body. Octavo, vi + 73 pages, 38 figures.

No. 156. Osborne, Thomas B., and Lafayette B. Mendel. Feeding Experiments with Isolated Food-Substances. Octavo, 53 pages, 22 text figures.

No. 157. Day, Arthur L., and Robert B. Sosman. High Temperature Gas Thermometry. With an Investigation of the Metals by E. T. Allen. Octavo, v + 129 pages, 18 figures.

Classics of International Law. Zouche, Richard. Juris et Judicii Fecialis sive Juris inter Gentes et Quæstionum de Eodem Explicatio. Vol. I. xvi + 220 pages.

Sales of Publications and Value of Those on Hand. The following table shows the amounts received from subscriptions to the Index Medicus, from sales of Year Books, and from sales of all other publications for each year since the foundation of the Institution:

Table showing sales of publications.

Year.	Index Medicus.	Year Book.	Miscellaneous Books.
1903	$2,256.91	$29.25	....
1904	2,370.47	52.85	$12.75
1905	2,562.76	44.75	431.44
1906	2,970.56	37.60	1,341.52
1907	3,676.71	56.50	2,292.89
1908	3,406.19	99.65	4,371.67
1909	4,821.85	73.01	6,287.21
1910	4,470.50	100.70	5,899.05
1911	4,440.21	85.50	6,366.55
Total..	30,976.16	579.81	27,003.08

At the end of the fiscal year just closed there are on hand 78,114 volumes of miscellaneous publications and Year Books, having a sale value of $173,158.20. There are also on hand 27,377 numbers, or the equivalent of about 2,100 volumes, of the Index Medicus, having a sale value of $12,594. The total value of publications on hand is therefore $185,752.20.

In connection with the above statement it is fitting to add that since the foundation of the Institution there have been distributed, chiefly by gifts to libraries and to authors, but to a noteworthy extent, also, by sales, a total of 90,730 volumes of publications of the Institution.

REPORT OF THE EXECUTIVE COMMITTEE

REPORT OF THE EXECUTIVE COMMITTEE.

To the Trustees of the Carnegie Institution of Washington:

GENTLEMEN: Article V, Section 3, of the By-laws provides that the Executive Committee shall submit at the annual meeting of the Board of Trustees a report for publication, and Article VI, Section 3, provides that the Executive Committee shall also submit, at the same time, a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year. In accordance with these provisions, the Executive Committee herewith respectfully submits its report for the year 1910–1911.

During the fiscal year ending October 31, 1911, the Executive Committee held nine meetings, including a special meeting on January 24, 1911, for the purpose of accepting the Founder's gift of an addition of $10,000,000 to the Endowment Fund of the Institution. Printed reports of these meetings have been sent to the members of the Board of Trustees.

Upon the adjournment of the Board of Trustees on December 13, 1910, the members of the Executive Committee met and organized by the election of Mr. Welch as Chairman for 1911, and by voting that Mr. Gilbert, Assistant Secretary of the Institution, act as Secretary of the Committee for the same period.

The President's report gives in detail the results of the work of the Institution for the fiscal year 1910–1911, together with itemized financial statements for the same period and a summary of receipts and expenditures of the Institution to date. The President also submits various recommendations and suggestions and an outline of suggested appropriations for the year 1912. The Executive Committee hereby approves the report of the President, and his recommendations, as the report and recommendations of the Committee.

In accordance with the wishes of the Founder, as expressed in his letter of January 19, 1911, accompanying his most recent gift to the Institution, and in accordance with the instructions of the Trustees, formulated at their meeting of February 18, 1911, the Executive Committee has opened an account with the United States Trust Company of New York, to be known as the Reserve Fund Account, and the sum of $250,000 has been credited to this account for the year 1911.

The question of the disposition of the income of the Reserve Fund was considered at the meeting of the Executive Committee on October 19, 1911, and, with the concurrence of Messrs. Low and Pritchett of the Finance Committee, it was voted to recommend to the Board of Trustees that the income of the Reserve Fund be credited to the principal of said fund.

The Board of Trustees at its meeting of December 13, 1910, appointed The American Audit Company to audit the accounts of the Institution for the fiscal year ending October 31, 1911, and the report of this company is herewith submitted as a part of the report of the Executive Committee.

There are also submitted a financial statement and a statement of receipts and disbursements for the year, together with a statement of aggregate receipts and disbursements since the organization of the Institution, on January 28, 1902.

There are no vacancies in the Board of Trustees, but the terms of office of Messrs. Root and Walcott as members of the Executive Committee expire with the coming annual meeting.

William H. Welch, *Chairman.*
John S. Billings.
Cleveland H. Dodge.
S. Weir Mitchell.
Wm. Barclay Parsons.
Elihu Root.
Charles D. Walcott.
Robert S. Woodward.

December 14, 1911.

Financial Statement, October 31, 1911.

		ASSETS.	LIABILITIES.
Endowment			$22,000,000
Sundry Reserve Funds:			
Reserve Fund and accrued interest			251,632.12
Insurance Fund and accrued interest			29,051.74
Profit from sale of bonds			1,893.75
Bonds:			
Endowment:			
U. S. Steel Corporation, Reg. 50 yr. 5 per cent gold bonds, Apr. 1, 1951		$22,000,000	
Reserve fund	$251,632.12		
Cash U. S. Trust Company (see page 36)	201,755.72		
$50,000 N. P.-Gt. North'n joint C. B. & Q. col., July, 1921	49,876.40	*49,876.40	
Investment:			
$50,000 A., T. & S. Fe R. Co. 4 per cent 100-year gold bonds, Oct. 1, 1995		*50,056.25	
$50,000 L. S. & Mich. S. Ry. 4 per cent debenture bonds, Sept. 1, 1928		*48,222.22	
$50,000 C. Pacific First Refunding gold 4 per cent bonds, Aug. 1, 1949		*51,937.50	
Carried forward		22,210,092.37	22,282,587.61

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* Purchase value.

Brought forward		$22,210,092.37	$22,282,587.61
Real Estate, Equipment, and Publications:			
Administration:			
Building, site, and equipment		319,220.67	
Publications:			
Stock on hand and outstanding accounts (Oct. 31, 1911)		186,639.28	
Department of Botanical Research (Sept. 30, 1911):			
Buildings, office, and operating	$34,634.02		
Laboratory equipment	7,259.53		
		41,893.55	
Department of Experimental Evolution (Sept. 30, 1911):			
Buildings, office, and library	39,887.04		
Laboratory apparatus	4,527.02		
Operating appliances and grounds	16,000.68		
		60,414.74	
Geophysical Laboratory (Sept. 30, 1911):			
Building, library, operating appliances	113,310.81		
Laboratory apparatus	60,361.47		
Shop equipment	10,742.20		
		184,414.48	
Department of Marine Biology (Sept. 30, 1911):			
Vessels	31,674.95		
Buildings, docks, furniture, and library	10,055.88		
Apparatus and instruments	2,515.82		
		44.246.65	
Department of Meridian Astrometry (July 31, 1911):			
Buildings and operating appliances	13,518.90		
Apparatus and instruments	2,394.34		
		15,913.24	
Nutrition Laboratory (Sept. 30, 1911):			
Building and office equipment	109,591.73		
Laboratory apparatus	10,893.89		
Shop equipment	1,923.33		
		122,408.95	
Solar Observatory (August 31, 1911):			
Buildings, grounds, road, and telephone line	120,464.79		
Shop equipment	19,304.65		
Astronomical instruments	315,463.67		
Furniture and operative appliances	50,746.90		
Hooker 100-inch reflector	49,965.91		
		555,945.92	
Department of Terrestrial Magnetism (Sept. 30, 1911):			
Office	4,697.42		
Instruments	25,214.13		
Vessel and ocean equipment	117,019.48		
Land equipment	4,409.02		
		151,340.05	
Property Investment (aggregate cost)			1,682,437.53
Grants:			
Large			149,188.44
Minor			27,727.47
Research Associates and Assistants			8,945.38
Publication			92,012.99
Administration			20,561.22
Cash:			
In banks (see page 36)		476,703.16	
Stamps and petty cash fund		300	
Unappropriated Fund			96,082.42
		24,359,533.06	24,359,533.06

Statement of Receipts and Disbursements from November 1, 1910, to October 31, 1911.

RECEIPTS.

INTEREST:		
U. S. Steel Corp. bonds	$975,000	
A., T. & S. Fe Ry. "	2,000	
Central Pacific "	2,000	
L. S. and Mich. S. "	2,000	
N. Pacific-Gt. N. "	1,500	
Deposits in banks	7,017.63	
		$989,517.63
SALES OF PUBLICATIONS:		
Index Medicus	4,440.21	
Year Book	85.50	
Miscellaneous Books	6,366.55	
		10,892.26
REFUND ON GRANTS:		
Grant No. 683	1,322.32	
654	170.82	
151	95.37	
425	94.73	
682	1,020	
679	1,512.30	
681	21.33	
		4,236.87
MISCELLANEOUS:		
Sale of copper	13.50	
paper	770	
Refund, express	3.35	
shipping	104.28	
telephone and light	29.53	
office	2.50	
		923.16
		1,005,569.92
Balance from last report to Trustees, Oct. 31, 1910		132,749.55
		1,138,319.47

DISBURSEMENTS.

INVESTMENT:		
Building (administration)	$2,045.39	
Bonds (Northern Pacific-Great N.)	49,876.40	
		$51,921.79
GRANTS:		
Large	463,609.75	
Minor	40,440.40	
Research associates	22,608.40	
		526,658.55
Publication	....	37,580.17
ADMINISTRATION:		
Trustees	3,262.14	
Executive Committee	2,931.79	
Salaries	24,800	
Publication—shipping expenses	3,300.79	
Insurance and surety	90.08	
Fuel, light, telephone	912.20	
Equipment	* 4,316	
Stationery	234.22	
Postage, express, etc	405.44	
Printing	† 2,496.94	
Building supplies and repairs	2,104.09	
Office supplies and petty expenses	602.11	
		45,455.80
		661,616.31
CASH IN BANKS:		
U. S. Trust Co., N. Y.	260,677.77	
U. S. Trust Co., Reserve Fund	201,755.72	
National City Bank, N. Y.	11,479.71	
American S. & T. Co., D. C.	2,789.96	
		476,703.16
		1,138,319.47

* Including charge of $3,600.50 for portrait of Founder.
† Including Year Book for 1910.

Statement of Aggregate Receipts and Disbursements from Organization, January 28, 1902, to October 31, 1911.

RECEIPTS.		
INTEREST:		
U. S. Steel Corporation bonds	$5,475,000	
A., T. & S. Fe Ry. bonds	29,483.34	
N. Pac. Ry. Co. bonds	24,055.55	
N. Pac.-Great N. bonds	10,000	
Central Pacific bonds	14,000	
L. S. and Mich. S. bonds	16,000	
Deposits in banks	78,688.91	
		$5,647,227.80
SALES OF PUBLICATIONS:		
Index Medicus	30,976.16	
Year Book	579.81	
Miscellaneous	27,003.08	
		58,559.05
REFUND ON GRANTS	....	14,237.10
MISCELLANEOUS:		
Organization	1,825.52	
Sale of furniture	69	
Gas deposit	5.36	
Postage, express, and travel	56.65	
Printing and paper	2,072.54	
Sale of metal cuts	61.80	
separates	22.15	
Refund, shipping	157.75	
grounds	38.46	
office	42.66	
insurance	4,717	
operating	18	
telephone, light	29.53	
		9,116.42
SALE OF BONDS:		
N. Pac.-Great Nor.	48,000	
Northern Pacific	102,750	
A., T. & S. Fe	49,500	
		200,250
		5,929,390.37

DISBURSEMENTS.		
INVESTMENT:		
Bonds	$398,448.62	
Administration Building and site	309,915.69	
		$708,364.31
GRANTS:		
Large	3,047,287.30	
Minor	757,507.97	
Research associates and assistants	* 203,745.11	
		4,008,540.38
PUBLICATION	....	318,804.13
ADMINISTRATION:		
Trustees	17,887.30	
Executive Committee	15,441.72	
Honorariums to advisers	17,319.81	
Salaries	250,613.03	
Publication—shipping expenses	7,648.02	
Insurance and surety	2,774	
Rent and fuel	27,417.24	
Equipment	11,326.98	
Stationery	11,685.47	
Postage and express	18,465.33	
Printing	† 22,615.75	
Building expenses	4,550.36	
Seal	555.60	
Organization	1,825.52	
Plans and option	5,166.46	
Office expenses	1,508.33	
Miscellaneous	70.23	
		416,871.15
REFUND:		
Publication	20.25	
Index Medicus	86.99	
		107.24
		5,452,687.21
CASH IN BANKS		476,703.16
		5,929,390.37

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* Including Special Grants of 1904, 1905 ($37,408.84).

† Including Year Books.

REPORT OF AUDITOR.

WASHINGTON, D. C., *November 28, 1911.*

The Executive Committee,
Carnegie Institution of Washington, Washington, D. C.

GENTLEMEN: The books and accounts of the Carnegie Institution of Washington have been audited by us from November 1, 1910, to October 31, 1911, by authority of the Chairman of the Board of Trustees.

We did not, however, audit the books of the various departments, as that is done by the Bursar and his associates, but we did verify the totals as carried from the subsidiary books to the general books.

The income from the Endowment Fund and from Investments has been duly accounted for, and the expenditures have been regularly authorized and are supported by proper vouchers.

On Tuesday, November 24, 1911, the undersigned, Mr. Otto Luebkert, in company with the Hon. Seth Low, Chairman of the Finance Committee, and Dr. Henry S. Pritchett, attended at the vaults of the Hudson Trust Company, Hoboken, New Jersey, and examined the bonds of the Endowment Fund, amounting to $22,000,000, finding same on hand and in proper order.

On the same day, Mr. Luebkert, in company with Mr. Low, visited the United States Trust Company, New York, and examined and found correct the bonds comprising the Reserve Fund, amounting to $50,000.

On Friday, November 17, 1911, Mr. Luebkert, in company with the Bursar, Mr. John L. Wirt, and the Assistant Secretary, Mr. W. M. Gilbert, visited the vaults of The American Security and Trust Company, Washington, D. C., and examined and found correct and in good order the securities comprising the Investment Account, amounting to $150,000.

Respectfully submitted.

THE AMERICAN AUDIT COMPANY,
By OTTO LUEBKERT, *Resident Vice-President.*

Approved:
F. W. LAFRENTZ, *President.*

[Seal of the American Audit Company, New York.]

Attest:
A. F. LAFRENTZ, *Asst. Secretary.*

BIBLIOGRAPHY OF PUBLICATIONS RELATING TO WORK ACCOMPLISHED BY GRANTEES AND ASSOCIATES.

Under this heading it is sought to include titles of all publications bearing upon work done under grants from the Carnegie Institution of Washington, exclusive of the regular publications. A list of the latter which have appeared during the year will be found in the President's Report (pp. 27, 28). The following list for the year 1911 has been made as complete as possible, and in some cases titles may be included which have only an indirect connection with grants from the Institution:

Abetti, Giorgio, and Ruth Emily Smith. Photographic observations of prominences. (Astrophys. Jour.)

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Adams, Frank D. An experimental investigation into the flow of rocks. (Reports of the 11th International Geological Congress, Stockholm.)

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Ault, J. P. Daylight observations on Venus. (Bull. Amer. Geog. Soc., v. 43, No. 10, pp. 767–770. Oct. 1911.)

Babcock, Harold D. The Zeeman effect for chromium. (Astrophys. Jour.)

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BAUER, L. A. Life and work of Robert Were Fox, 1789–1877. (Terr. Mag., v. XV, No. 4, pp. 207–208 with pl. V. Dec. 1910.)

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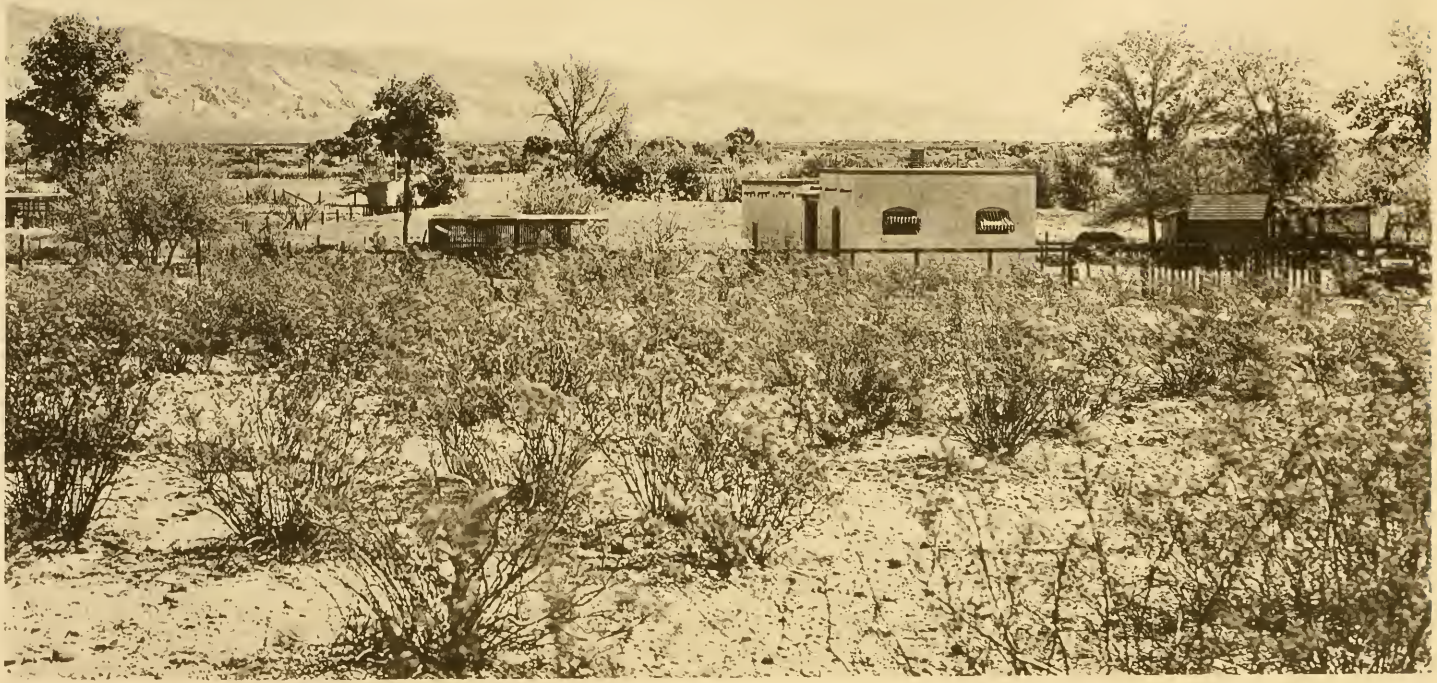
REPORTS ON INVESTIGATIONS AND PROJECTS

The following reports and abstracts of reports show the progress of investigations carried on during the year, including not only those authorized for 1911, but others on which work has been continued from prior years. Reports of Directors of Departments are given first, followed by reports of recipients of grants for other investigations, the latter arranged according to subjects.

PLATE 1



Buildings of Desert Laboratory, Tucson, April 13, 1911.

DEPARTMENT OF BOTANICAL RESEARCH.*

D. T. MacDougal, Director.

Definite progress may be reported in the attainment of experimental results concerning environic response and physical relations of plants and animals, in the determination and calibration of photosynthetic and other photochemical activities of green plants, in the coördination of data which establish some major conclusions as to climatological history during recent time, and in the accomplishment of systematic observations which yield conclusions of importance as to the origin and fate of plant population in the course of such climatic alterations. The recession of Salton Lake has now reached an anticipated stage in which a general summarization of its consequences may be profitably made, and the preparation of a volume dealing with the principal physical and biological phenomena disclosed by several collaborators has been begun. It is gratifying to record that it has been possible to put into effect and continue coöperative arrangements of substantial importance with research associates and workers representing many different kinds of scientific effort and several institutions.

THE SURFACE GEOLOGY AND VEGETATION OF SALTON BASIN.

The observations upon Salton Lake and its effect upon the vegetation of the basin in which it lies have now been carried on for six years. The original maximum depth of the water of 84 feet has been reduced by an evaporation of about 72 inches yearly. Of this theoretical total, however, amounting to 310 inches, 12 feet have been replaced by inflow of precipitated water, underflow from the mountain drainage, and waste from artesian wells and the irrigation systems which have been developed in the southern parts of the basin around the towns of Brawley, Imperial, El Centro, Holtville, Heber, and Calexico.

The recession of the margin of the lake has resulted in uncovering an area of about 100 square miles. The horizontal movement has of course depended directly upon the gradient. This was gentlest at the northwestern and southeastern ends of the lake, and in places the water does not come within 3 miles of the limits reached in 1907.

The lowering of the level of the lake has of course not proceeded regularly. Extended periods have been noted during which the level remained fairly constant by reason of the lowered rate of evaporation and the volume of the inflow. This fact, together with the seasonal action of the vegetation in maturing seeds and propagative bodies, has furnished some phenomena of reoccupation of exceptional interest.

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* Situated at Tucson, Arizona. Grant No. 674. $35,680 for investigations and maintenance during 1911. (For previous reports see Year Books Nos. 2-9.)

The salt-content of the water was over 0.25 per cent at the maximum level in 1906. This has now increased to 0.72 per cent. The investigation of various problems connected with the making and desiccation of the lake has now proceeded far enough to make some interpretation and correlation of results profitable and possible. The more important features will therefore be discussed in a manuscript now in course of preparation.

The Composition of the Water of Salton Lake, by Dr. W. H. Ross.

In accordance with the practice of previous years, a large sample of water was on June 3 taken from near the surface over the deepest part of the lake, under the personal supervision of Dr. Ross. The preliminary data from the analysis of this sample may be given as follows:

	Parts per 100,000.
Total solids dried at 110°, *plus* water of occlusion and hydration	718.00
Chlorine, Cl	339.00
Nitrates, NO_3	none
Nitrates, NO_2	none
Free, CO_2	0.72
Bicarbonic, HCO_3	17.14
Carbonic, CO_3 (in evaporated residue of the water)	5.78
Oxygen consumed	0.63

The total solids plus the water of occlusion and hydration have increased by 18.9 per cent over that found for last year, while the chlorine has increased by 20.8 per cent; the corresponding percentage increases of last year were 16.2 and 16.6. The bicarbonates in the water show a decrease, as noted in the report of the previous year. A number of samples were taken from the bottom of the lake and from localities widely separated from the surface, and the analysis of these samples shows that the whole body of water is remarkably uniform. This implies that the leaching from the beds covered by the water has removed the salts from the upper layers, so that diffusion goes on very slowly, and that the increasing salt-content of the lake is due almost wholly to the inwash of surface deposits around the lake and to the losses by evaporation. Although, as noted in a previous paragraph, a very considerable amount of fresh water is brought into the lake through the Alamo and New rivers, as well as from artesian wells, yet the wind action keeps the body of the water in the lake constantly stirred.

The Behavior of Unicellular Organisms in Condensing Brines, by Prof. G. J. Peirce.

The study of the micro-organisms in the brines of the salt works on the shore of the San Francisco Bay has been continued by weekly collections and by pure cultures of some of these organisms. The great range of concentration, from rain-diluted sea-water in winter to a brine containing 30 grams of solid matter in 100 c.c. in late summer, demands an extraordinary adjustment of the organisms to the changing environment. The organisms respond to the environmental changes by differences in the modes of reproduction as well as in vegetative ways. A quantitative chemical analysis of the concentrated brine shows a solution of remarkable composition as well as concentration. In these two respects it forms an extraordinary habitat for living organisms and presents problems of great physiological interest. The difficulties of the investigation are so great that progress is necessarily slow. In spite of this, enough definite results have been reached to encourage the student in further work.

A chromogenic bacillus has been isolated which has some economic importance. In addition to the existence of these micro-organisms in brine, they are found also on the crude salt produced in these salterns. As this salt is sometimes used without purification, they may be transferred to the material with which the salt is mingled and thus come into another and quite different environment. In this only the chromogenic bacteria have attracted attention. It is unlikely, however, that the others disappear or are entirely inactive, and further effort will be made to determine their fate.

Geological, Climatic, and Vegetational Features Presented by the Otero Basin, by Mr. E. E. Free.

Some information—interesting, especially in comparison with the Salton—has been obtained by a reconnaissance of the Otero Basin in south central New Mexico. Geologically this basin is a long, narrow, dropped block between two outward-tilted mountain ranges: the White and the Sacramento mountains on the east, the Organs and San Andreas on the west. As usual in arid basins, the valley has been deeply filled with alluvial material washed in from the surrounding mountains. The topography of the floor is also quite typical: a fairly steep bajada on alluvial slopes at the foot of the mountains merging into a flat and featureless plain which sinks very gently to a central playa.

In recent geologic time the basin has been occupied by a very variable lake fluctuating in response to changes in climate, overflowing in wet periods, retreating in dry, and leaving the records of these climatic vicissitudes in the deposits of its bottom and the topography of its borders. Of these deposits, the earliest whose history can be read with any surety are the beds of reddish gypsiferous, calcareous, and sometimes saline clay exposed in many places 10 to 30 feet under the surface of the basin, and which are almost certainly the deposits of this old lake during its last period of great expansion and overflow and during the first part of the following period of contraction and concentration. These so-called "red beds" are covered nearly everywhere by beds of granular, somewhat consolidate gypsum which are believed to be materials deposited at the borders and on the final dry playa of this evaporating lake and afterward whipped into dune form by the arid winds. This gypsum is so widespread in the basin that one must assume for its formation a long and intense period of aridity and of dune movement. This arid period was followed by a period of greater rainfall and of expansion of the lake, with resultant fixation, planation, and consolidation of the gypsum dunes.

This rainy period was both shorter and less intense than the preceding and was followed, in turn, by another but shorter period of aridity and the formation of gypsum dunes; a short period of relatively higher rainfall, when these dunes were covered and fixed by vegetation, and a later period of renewed aridity, which is still in progress and during which the present series of moving dunes of gypsum, known as the "white sands," have been formed. Even this last period has not been a unit, having been broken not very long ago by a short period of slightly greater rainfall and of dune vegetation and fixation. The records of this cycle of climatic change and of varying geologic action can be read in terraces, arroyos, lake strands, etc., as well as in the gypsum dunes, but are best exhibited in the latter, it being not infrequent to find the four successive series of dunes superposed, the one on the other.

These features, as well as the general aspects of the vegetation, afford invaluable comparative data in the interpretation of the phenomena afforded by the Salton. A small number of beach plants or succulents characteristic of saline soils are to be found in both places. Outside of this the species are different, but in their general association they offer landscapes quite like those of the Salton. Succulent desert plants are a small constituent of the floras, and the woody perennials do not reach any notable size. Emphasis is to be laid upon the fact that very few if any species are known which appear to be indigenous to either basin or to have originated there. It is evident that the wide variations in the soil conditions in both basins must operate against the survival of any species unless it is quickly disseminated beyond the borders of the basin, in which case its genetic connection with the locality would be lost.

REPORTS OF INVESTIGATORS.

Changes in Climate, by Prof. Ellsworth Huntington.

Dr. Huntington, as a research associate of the Institution, has found it profitable to carry on the major part of his work on variations in climatic factors in coöperation with this department. March and April were devoted to an examination of terraces, ruins, salt lakes, and other material in New Mexico furnishing critical data concerning the course of climate. May and June were spent in California making measurements of cross-sections of giant redwood trees (*Sequoia gigantea*), for the purpose of ascertaining to what extent possible variations might have been registered by the rate and manner of growth resulting in the annual rings.

The work in New Mexico began in company with members of the staff of the Desert Laboratory in the Otero Basin, in the southern part of the State, where about three weeks were spent. The two main lines of investigation were ruins in the midst of what is now an uninhabitable desert, and a series of gypsum sand dunes and old lacustrine strands which seem to indicate climatic fluctuations of some severity since the Glacial period. This was followed by visits to some of the more noted prehistoric sites in the central, northern, and northwestern parts of New Mexico. The purpose of these visits was to obtain a first-hand knowledge of some of the areas where archeologists are most actively at work, in order that the results of archeological and geographic studies may be brought into harmony. In this work Dr. Huntington received the cordial coöperation of the American Archeological Institute through the curator of its museum at Santa Fé, Mr. Kenneth M. Chapman. The last piece of work in New Mexico was a visit to the so-called prehistoric dam of colossal size which has been reported by various travelers in the extreme southwestern corner of the State. The dam proved to be unquestionably the work of nature, not of man. It is merely an old lake strand, although it has been described by other investigators in detail as the work of human hands. A number of ruins were found in the region, however, proving that a fairly abundant population once existed even in this out-of-the-way corner.

The two months spent by Dr. Huntington in California were devoted to minute measurements of the thickness of the rings of annual growth of giant redwood trees, which have been cut for lumber during the past generation. In this he was assisted by H. E. Miller, of Elk Grove, California, and D. B. Cohen, of Oakland, California. About 200 stumps were measured, varying in age from 2,300 to 3,150 years; 42 of these trees began their growth more than 2,000 years ago, and three more than 3,000 years ago. The thickness of the growth was measured for each decade from the beginning to the present. The 40,000 numbers thus obtained are being examined, and from them it will be possible to prepare a curve showing, with considerable clearness, the main climatic fluctuations for at least 2,000 years. Preliminary partial computations indicate that this curve will show close resemblance to the climatic curve computed from evidence of a totally different character obtained in Asia. In order to test the matter more fully, trees of other species are being used, not only in California, but in various parts of the United States. For this purpose the United States Forest Service, through Mr. H. S. Graves, Forester, has placed at the disposal of the Institution all its thousands of stem analyses, many of which were taken from trees 2 to 1,200 years of age. The curves derived from all of these will be published with those of the sequoias in the report on the ancient climate of America, which is in preparation by Dr. Huntington.

Inductive Influence of Climatic Complexes upon Organisms, by Dr. D. T. MacDougal.

The comparative culture of a number of selected species in the desert, maritime, and montane plantations are already yielding some facts of wide interest as to possibilities in geographic movements in addition to the environic reactions, the determination of which is the prime purpose of the investigation. Thus perennial forms native to the lowlands of eastern America (with a growing season of 168 to 170 days and a winter with extended exposures below the freezing-point) endure the climate of the montane plantation in Arizona at 8,000 feet, where the growing season is scarcely over 100 days, in which alternations of aridity and humidity are rapid and frequent and the winter conditions severe. Next it is seen that such plants as *Scrophularia* (or figwort) and *Fragaria* (wild strawberry) from New York, which thrive at the montane plantation, together with plants taken from this elevated region, survive and exhibit a most luxuriant growth at the maritime plantation. A comparison of climatic data from the montane plantation (at 8,000 feet in southern Arizona) with instrumental records at the maritime plantation at Carmel shows that the temperature conditions on the mountain, which range between about 47° F. and 85° F. during the growing season, are practically duplicated during the entire year at the maritime plantation, a most unexpected similarity and one which it is believed has not before been recognized by naturalists. The replacement of the summer rains on the mountain by a season of fogs at the maritime plantation gives sufficient difference to yield some highly pronounced experimental results. Among these may be mentioned suppression of reproduction in some species, stimulation in others, atrophies of stems and leaves in some, exaggeration of vegetative organs and multiplication and divergence of floral organs in others, according to habit and physiological qualities.

Species indigenous to the region of the montane plantation survive when taken to the foot of the mountain, although never successful in making such descent unaided, with two possible exceptions. Species from the arid regions may survive in the equable maritime climate, but the fleshy succulents from this region quickly perish when taken to the desert, demonstrating the wide difference between the succulents of the desert (such as cacti) and the fleshy plants of beaches.

From the mass of detail included in the experimental records may also be extracted the surprising fact that spineless or nearly spineless cacti (Opuntias) from Arizona develop and retain a decided armature when grown at the maritime plantation. None of the attempts hitherto made to perfect a theoretical conception which would be useful in interpreting the mechanism of environic responses have had anything more than the most limited usefulness. The stimuli of climatic and many other agencies do not imply the introduction of any strange or new substances into the bodies of the organs affected. These agencies might change the dissociations in such a manner as to modify the relative number of free ions and thus alter the molecular complex of the living matter in a very important manner. The intricate play of enzymatic action might also be altered, and any modification of the relative reaction velocities of the more important processes might result in material and permanent change, especially in those cases in which external agencies interfere directly with the action of the germ-plasm.

It is to be noted that the experimental results obtained at the plantations reach their full value only when parallel analytical cultures are made in inclosed chambers in which all of the environic factors may be fully controlled and exactly calibrated.

The Hibernation of a Desert Beetle (Leptinotarsa decemlineata), by J. K. Breitenbecker.

The extensive cultures of *Leptinotarsa,* which have been carried on chiefly for the purpose of obtaining results in connection with Prof. W. L. Tower's researches upon the influence of environment on heredity, have furnished opportunities for an experimental study of the habits of these beetles in the desert climate of Tucson, which runs a course generally parallel to that of the original habitat in southern Mexico. Two generations are produced annually, and the later one each year usually goes down into the soil to a depth of a few centimeters to a point where the optimum water and air content is found and remains dormant until awakened by certain climatic combinations. The hibernating period may vary from a few months to several years. Experimental arrangements show that either generation may be induced to hibernate, and also that hibernation may be eliminated for an indefinite number of generations by hybridization and controlled climatic conditions.

The fundamental activities of this beetle, as well as those of many desert organisms, are directly conditioned by its water-content or water-balance. The water-content of the beetle is determined by the evaporating capacity of the air, the leaf-moisture content of its food-plants, soil-moisture, and temperature. Variation in any of these factors may influence not only the hibernation, but other habits and reactions.

Vital Statistics of Desert Plants, by Dr. Forrest Shreve.

Work has continued on the vital statistics of the giant cactus (*Carnegiea*), palo verde (*Parkinsonia*), and ocotillo (*Fouquieria*). Detailed weekly observation of a small area has been made, resulting in an exact record of the germinations and deaths of the above species, together with which has been secured a record of the conditions of atmospheric and soil moisture, upon which the death-rate of seedlings depends. The continuation of this work has emphasized the differences of behavior in establishment that characterize the different types of desert succulents and sclerophylls. It also emphasizes the extreme slowness with which even the most typical desert species are able to establish new individuals. Observations will be continued on the same area, henceforth at longer intervals, in order to observe the influence of good and poor seed crops on germination-rate and the effect of the annual variations in amount and incidence of seasonal rainfall on the death-rate of individuals of all ages.

Additional work has been done on natural populations of palo verde in several localities, in which the rate of establishment for the past 300 years has been determined, by converting the trunk-diameter measurements for the whole population into ages, known through averaged counts of annual rings. While the results for the seventeenth and eighteenth centuries are subject to errors that will necessitate much additional work, the curves for the nineteenth century indicate a decrease in the establishment rate. This is in harmony with results secured with the giant cactus by similar methods, and seems to point to an increasingly unfavorable incidence of the rainfall of the germinating season, without regard to its amount.

Vegetation in the Santa Catalina Mountains, by Dr. Forrest Shreve.

The work which has been under way for several years on the climate and vegetation of the Santa Catalina Mountains has been actively prosecuted during the past summer and brought to a close. The instrumentation has been made more complete than in previous years. Records of rainfall have been secured at six stations separated by vertical intervals of 1,000 feet, and at each of these stations a record of evaporation-rate for the growing season has been secured for both southern and northern exposures. Hygrographs were operated at 4,000 and 7,000 feet altitude, and a daily record of maximum and minimum temperatures at 8,000 feet was secured through the coöperation of Mr. J. G. Brown. Determinations of soil moisture for northern and southern slopes at the six stations were also made at critical times in the growing season. The conditions of atmospheric and soil aridity prevailing in the desert during the dry foresummer have been found to extend, with far less amelioration than was supposed, to the heavily forested altitudes; the midsummer rainy period, however, being one of great differentiation at the several elevations.

Data are now in hand to work out a number of features of correlation between the distribution of vegetation and that of the chief environmental factors.

Climatic Control of Growth Activities, by Dr. Forrest Shreve.

Field work has been carried on with a view to determining the growth-rate and establishment-rate of the Arizona yellow pine (*Pinus arizonica*) at four elevations, 1,000 vertical feet apart, within its natural range in the Santa Catalina Mountains. Observations have been made on areas of 1 hectare in typical localities with southern exposure, and have been taken so as to show total population, diameter of all individuals, height of individuals less than 3 meters high, and the age of selected individuals of all ages, as determined by ring count. These data make it possible to determine the curve of average growth-rate for the pine at different ages, and its curve of average growth-rate during the past 100 years. These two curves, secured for each of the several altitudes, show graphically the greater activity at the higher elevations, in both growth and establishment. When these data are viewed together with those on the climate of the Santa Catalina Mountains, they form an addition to our knowledge of the correlation between distribution of climatic conditions and the activities of the same species under these distinct conditions.

Influence of Low Temperatures on Giant Cactus, by Dr. Forrest Shreve.

Experimental evidence has been secured going to show that the giant cactus (*Carnegiea*) is capable of withstanding below-freezing temperatures for periods of 16 to 20 hours, but is not able to survive such exposure for 30 to 40 hours. In the desert valleys of southern Arizona freezing temperatures never persist over an entire day, the longest single period of frost recorded for Tucson being 19 hours. The distributional limit of the giant cactus is so situated as to indicate that its inability to withstand a duration of frost of 30 to 40 hours is the factor responsible for the limitation of its northward extension and of its vertical range in the desert mountains. These results suggest the importance of winter-cold factors in limiting the distribution of desert species on the slopes of the larger desert mountains and at the more elevated or more northerly edges of the American Desert, and would appear to account for the inability of some of the desert species to migrate into regions of more favorable moisture conditions, out of which "competition of better adapted species" has been supposed to keep them.

Evolution of the Chrysomelid Beetles of the Genus Leptinotarsa, by Prof. W. L. Tower.

The present report is a very brief résumé of the chief operations and of the results thus far obtained at the Desert Botanical Laboratory during the seasons of 1910 and 1911. Throughout the two years the conditions have been, so far as these animals are concerned, unusually severe, even for these desert areas, and the labor of maintaining the experiments has therefore been greatly increased. Many new and minor problems have arisen, which demand time and attention in order that the major objects of the investigation might not suffer. The immediate care and oversight of the experiments have been in the keeping of Mr. J. K. Breitenbecker during both years, and to his enthusiastic aid much of our success is due. Many of the minor problems that were presented at the beginning of the work at Tucson have been eliminated, especially the question of supply of food; no further difficulty is anticipated in maintaining the necessary food supply with the minimum expenditure of time and energy. The measurement of the conditions under which the different experiments are carried on has consumed considerable time, and there are now available long series of determinations and measurements of the natural conditions surrounding the cultures and of the effect of the cages in damping or intensifying any of the factors of the natural environment. An unusually complete picture of the physical conditions in these experiments is now available. It is usual in work of this kind to employ the records of the nearest Weather Bureau station, or some other convenient meteorological records. But the measurements made in the last two years at our stations A, B, and C show marked and permanent daily, monthly, and annual differences, although these locations are so near one another that they would ordinarily have been called one. It is therefore demonstrated that special observations must be made for the purposes of experiments of this kind.

During 1910 and 1911 the introduction of species of *Leptinotarsa* from different regions of the American continent has been continued. At Tucson, with its typical subtropical desert, all introductions thus far made act in the same manner; that is, the ability of the introduced race to survive is not a question of food or enemies, but the attainment at some time during the year of the proper complex which will allow the introduced form to breed and permit the progeny to attain their growth. It is found that the different introduced species, coming from a wide range of original habitats, are alike in this respect, and food, enemies, and relation to other activities are minor in importance; most vital is the ability to breed, and secondly to pass the dry or winter season in successful suspension of active metabolism, in partial or complete hibernation. The breeding activity is in reality the central factor in determining the survival of the introduction, and this depends entirely upon the physical environment, and at this station the water relation is the chief efficient factor in the complex. In all of these organisms there is a very exact and permanent balance for each species; and, while all are in principle the same, the response to the water-content of the physical environment is a narrowly fixed minimum, characteristic and exact for each species. This is also a fully inherited character, which is alternative in its behavior in crosses. This relation in the introduced species often causes curiously irregular behavior. They may have to wait for some months, or even for a year or more, before the proper complex is reached, and while a close approach to the proper state will often produce the beginnings of reproductive activity, these are not completed unless the proper state is attained. Many of these false starts are made in some cultures only to result in partly developed eggs and sperm, which then are resorbed, or frequently produce derangements fatal in effect.

Nearly as important in determining the fate of these introductions are the relations to the water-content needed for the passing of the winter or dry season, which often causes the elimination of a large part of the population, or sometimes all of it. At Tucson the water relation, as might be expected, is the chief factor in the hibernation activities, and is of vital importance to the organism in directing the outcome in the struggle for existence; but this relation would not of necessity be an efficient modifying factor in the further evolution of the race. The fact that the breeding activities of the race do not take place until a certain condition of the environment is attained would in many introductions destroy all chance of evolution due to changed environment, so that the mere fact of introduction into a new environment is not always a factor of evolutionary importance.

Direct evidence that changed conditions of existence do produce inheritable modifications in animals, both in nature and in experiments in the laboratory, was most clearly shown in a series of experiments brought to a focus in the past two years. A pure stock of *L. diversa* was taken as the basis; a fraternal group of well-pedigreed cultures was divided into three portions; one was sent to Tucson and reproduced under the conditions of the moist midsummer of 1910; a second was placed under experimental conditions at Chicago, which duplicated in average intensity and daily range the chief environmental factors at Tucson; a third was kept in the normal conditions to which the strain had been accustomed for many years. The result was the production of identical modifications in the experimental cultures at Tucson and at Chicago, and the non-modification of the group which was allowed to breed under normal conditions. The culture at Tucson passed the winter of 1910–1911 in hibernation and the count of the material in the spring of 1911 showed 66 unmodified and 115 modified. In the Chicago portion of the experiment essentially the same proportion of the culture was changed, and these on further breeding have proven to be inheritable variations. During this time the main stock, as well as the control culture, has not shown the least trace of the modifications produced in the two experiments. It is of interest to obtain in the same homogeneous material the same results in experiments, in nature and in the laboratory.

One of the first lines of investigation started at Tucson was the effort to create and maintain a race which should mutate in the manner of *O. lamarckiana,* and then to determine the relation of the extent and frequency of the mutations to the variation of the environmental conditions of the culture. It developed early that apparently similar races could be produced if freely inbreeding species were allowed to inbreed at liberty, and that the outcome was, in the huge majority of instances, the production of a stable race that at intervals gave sports, which were the reappearance of the attributes entering into the original combinations. Several such combinations were made at Tucson in the beginning, and in the earlier years these speedily settled down to a stable type with the normal fluctuating variability. These combinations are no more prone to wide variation than are the natural species, and under fairly constant conditions continue to breed true at Tucson and at Chicago, whence some of them have been taken to be tested.

In the years 1910 and 1911 some of these cultures have been tested to determine the rôle that changing or intensified conditions would have in the production of rhythmic mutability. In the tests each culture was divided, and part was tested and part kept under normal conditions. In all of the cultures it has thus far been the experience that the experimented culture has given an increased variability and in all cases a greater or less array of mutants. One of these tested cultures has given, under the intensified conditions, an increased mutability, generation after generation, in much the same manner that *O. lamarckiana* does. One of the most interesting of the cultures has given, in the two generations of 1911, types that are recombinations of the attributes that went into the original combination, and some of these had not been present in the hybrid combination or in the parent stock for ten or more generations. The general outcome of these experiments at Tucson and in other locations indicates that we are dealing with a potent means of evolution, especially in the formation of specific types through the synthetic recombination of existing attributes. The behavior of these stable races, produced through these experiments, is precisely that of many species in nature, and some of them (in their permanent dimorphism or polymorphism) are in all respects similar to dimorphic and polymorphic species in nature; and their activities (especially in analytical experiments) leads me to believe that the numerous instances of dimorphism and polymorphism probably have a similar origin in nature. The present cultures of this type will be continued and an increased array of investigations of this sort will be initiated in the future. During the years 1910 and 1911 there have been introduced into the cultures at the laboratory a considerable number of stable hybrid combinations which were produced in the laboratories at Chicago, many F_1 hybrids, and a considerable number of new creations from the same source. These are being tested as to their capacity to survive under the desert conditions, the possibility of being further modified by changed environment, and the possible reversion to the original condition. Thus far not the slightest trace of reversion in the Darwinian sense has been discovered. The season of 1911 marks the close of four years of operations at this station, and during these years a considerable body of data has been collected, from which some of the broader lines of investigation, with the conclusions thus far derived, are here indicated. These years have been, however, more in the nature of a preparatory period in the perfection of methods and the ability to handle the natural environmental complex for experimental purposes to the best advantage. These methods of work, the results obtained, and the determinations of the physical environment that have been made will be ready for publication in the near future.

Certain of the experiments now under way at the laboratory will be brought to an end this year and in their place new and more complicated investigations are being organized. For that portion of my work requiring a desert location, none better than that found at the Desert Botanical Laboratory could be desired. The advantageous location, the interest taken by the Director of the Laboratory in facilitating this work, and the liberality of the Carnegie Institution of Washington in providing anything that has been needed in the investigation have contributed much to the rapid progress which it has been possible to make in the four years of operations.

Botanical Features of Algerian Deserts, by Dr. W. A. Cannon.

Dr. Cannon started from Algiers in October 1910, and followed a route in the desert which carried him across the Tell, the High Plateau, and the Atlas Mountains nearly directly southward to Laghouat and Ghardaia, then to Touggourt by way of Ouargla. From Touggourt the return was made by the Oued Rirh to Biskra, thence to the starting-point. The entire journey included over 1,000 miles of desert travel by diligence, motor cycle, and camel train. A brief trip was made also up the Nile as far as Assouan to obtain comparative data, and then a return was made in March to Biskra for the purpose of completing certain exact observations.

The reduction and compilation of results has not yet been made, but the following general characterization of the vegetation and surface conditions may be presented at this time. It is to be noted that the region traversed offered a surface covered chiefly with stones, comparatively little sand being encountered. Gypsum is an important constituent of the soil, a hardpan is present, and water may be found (at varying depths) 3 or 4 feet below the surface at Ouargla, and over 400 feet below in the region of the "dayas" south of Laghouat. At Ouargla the superficial water is heavily charged with salts. The rainfall at Biskra averages about 9 inches annually and is considerably more than in the region farther to the south.

The region traversed is treeless, except in the "dayas" south of the Saharan Atlas Mountains. The plains bear inconspicuous shrubs of such meagerness as to give very little character to the landscape, although as many as 400 individuals might be counted in an area of 50 square feet. Some perennials bear small fleshy leaves, the roots of *Citrullus* are much thickened, and a small *Euphorbia,* also with roots somewhat fleshy, is rather common; yet distinct succulents or plants with a large water-balance are not components of the flora. The horizontal and superficially disposed root-systems such as are furnished by the cacti are not seen here and but few species have a deeply penetrating tap-root. The greater number of plants have a diffused or "generalized" root-system which, on the plain, penetrate to a depth of 3 feet or less, and in the oueds sometimes to 6 feet and possibly more. The physical relations of plants to the soils promise some close adjustments, as a number of species were seen at Ghardaia in November in leaf and flower, although no rain had occurred for a year.

Perhaps nowhere else in the world may such interesting results of the attacks of grazing animals on vegetation be seen. The gazelle (*Gazelle dorcas*) was doubtless very abundant in this region during the periods in which it has not been occupied by man, and the species is frequently encountered at the present time. Southern Algeria has been inhabited by Arabs for 800 years and large numbers of sheep, goats, and camels graze everything very closely. Although the vegetation on certain protected areas is more abundant than on the open plains, it is not certain that any species has been exterminated, although the form, number, and distribution of the species eaten has been greatly modified.

The Water-relations of Halophytes and Sclerophylls, by Prof. F. E. Lloyd.

Data were obtained for the determination of the absolute, relative, and cuticular transpiration of such beach plants as *Abronia latifolia, A. umbellata, Cakile americana,* and of trees and shrubs from neighboring slopes, including *Quercus agrifolia* and *Rhamnus purshiana.* A method was devised for observing the actual condition of stomata on living leaves by the use of strong illuminations and the higher powers of the microscope. The following tentative conclusions were reached:

(1) Little variation in the actual amount of water in the leaves was observed, and the rate of loss was low in the cool air and high humidities of the Carmel region in which the work was performed.

(2) The beach plants or halophytes showed a lively stomatal activity—a remarkable readiness to wilt and desiccate. In this particular such plants are widely different from the fleshy plants of the desert.

(3) The osmotic pressures of the thick leaves of beach plants are equivalent to 0.2 to 1.3 potassium nitrate, or 7.5 to 48 atmospheres. The pressure in the roots is notably lower, as in other plants.

(4) The amount of water-vapor which any of these plants may absorb from the air is small and of little significance in the life of the plant.

Irritability of the Stigma of Diplacus (Monkey-flower), by Prof. F. E. Lloyd.

The abundance of living material around the laboratory at Carmel led to the testing of the irrito-motile movements of the stigmas of *Diplacus,* which is one of a group in which the lips of the stigma are capable of pronounced movements on contact. These movements seem to take place only in cells actually pressed or deformed by the contact of a hard object, and no transmission of impulse occurs. The application of pollen does not constitute a stimulus and an interpretation of the phenomenon in question as an adaptive function is difficult to make.

The Water-balance of Succulents, by Dr. D. T. MacDougal.

Earlier results as to the amount, variation, and physiological value of the great balances of water accumulated by cacti have been brought out in Publication No. 141. A continuation of this work has yielded some further results of importance. The rate of daily loss of water by transpiration from massive cacti was seen to be as high as 1 in 300 of their total weight in *Echinocactus* (a globose form) and 1 in about 700 in *Carnegiea* (a cylindrical form). The lowest daily rate was 1 in 40,000 *Echinocactus* and 1 in 9,000 in *Carnegiea.*

Contrary to accepted generalizations, the rate of loss of water is not proportional to the degree of succulence or proportion of water present. A fair illustration is offered by an *Echinocactus* which transpired at a rate between 10 and 29 grams daily in 1908. A year later, when it had suffered a depletion of its water-balance amounting to 7 per cent, the rate fell to 4 to 15 grams daily, a decrease of more than 50 per cent. The decrease is not referable to heightened concentration of the sap, but must be due in the main to alterations in the character of the membranes and to changes in position of the surface folds, chiefly the first-named cause.

The great water-reserves of desert plants have value in making for endurance of arid seasons, yet it is notable that many species may not carry on growth or reproduction if the water-balance is depleted very much. The total losses and fate of a number of massive plants taken from the soil and placed on suitable supports in a laboratory and in the open are given below.

Name.	Original weight.	Total loss.	Proportion.	Period.
Echinocactus:			*Per ct.*	
No. 1	42.743 kg.	4.583 kg.	11	15 mo.; shaded room; died.
No. 2	5.136 kg.	1.724 kg.	33	18 mo.; shade and open air; living.
No. 4	1.192 kg.	0.643 kg.	54	36 mo.; died.
No. 6	28.573 kg.	3.713 kg.	13	30 mo.; shade; living.
No. 7	35.818 kg.	4.248 kg.	11	Do.
No. 13	49.390 kg.	23.850 kg.	48	13 mo.; open; living.
Carnegiea:				
No. 1	40.000 kg.	11.250 kg.	28	12 mo.; open air; shade; living.
No. 1*a*	45.325 kg.	10.535 kg.	23	16 mo.; open air; living.
20 seedlings	27.244 gm.	17.745 gm.	64.7	102 days; shade; 4 dead.
Brodiæa: 36 resting corms	46.700 gm.	27.435 gm.	59	96 days; shade; young corms formed.
Ibervillea:				
No. 0	530 gm.	143 gm.	27	19 mo.; shade; sending shoots up annually.
No. 4	1.424 kg.	164 gm.	11.5	14 mo.; shade; annual shoots.
No. 5	1.026 kg.	278 gm.	27	Do.
Tumamoca: Tuber.	125 gm.	34.4 gm.	17.5	4 mo.; shade; died.

Alterations in Heredity Induced by Ovarial Treatment, by Dr. D. T. MacDougal.

The cultures in which progeny derived from treated ovaries are being tested through three and four generations now include *Echinocereus fendleri, Echinocactus wislizeni, Brodiœa capitata, Fouquieria splendens, Sphœralcea pedata, Penstemon wrightii, Phytolacca decandra, Opuntia discata, Carnegiea gigantea, Amsinckia spectabilis,* and *Solanum eleœgnifolium.* Of these, lots from successive seasons are under observation from two species, in which some species are represented by two or more different treatments.

The announcement was made in 1908 that some divergent characters were seen in a treated progeny of *Cereus.* The plant in question, by the incessant changes of nomenclature, is known at the time of this writing as *Echinocereus fendleri.* The progeny is coming into bloom, and while one of the individuals diverges widely beyond the observed range of fluctuating variability, it can not yet be definitely stated whether or not the characters displayed are permanently heritable or not. This is to be determined by the behavior of the descendants of the second and third generations.

The derivative of *Oenothera biennis,* first obtained in 1905, has now been tested to the fifth generation, hybridized with the parental form, and cultivated under the most diverse conditions. No reasonable doubt as to its character remains.

Experimental studies such as are here described lead the investigator into the consideration of two phases of the subject. One is concerned with the demonstration of induced hereditary alterations and the study of their behavior in pedigreed strains, in hybridizations, and under various environic conditions. The other includes a consideration of the mechanism by which an environic agency affects the physical bearers of heredity. Both comprise important and interesting possibilities in evolutionary science.

Evaporation and Soil Moisture, by Dr. B. E. Livingston.

The study of the evaporating capacity of the air as a controlling factor in determining plant transpiration has been continued; the preliminary survey of this subject by quantitative methods, as originally planned, is now nearing completion, so that the various phases of the problem may soon be brought together. A newly investigated factor in the control of transpiration is the diurnal variation of the moisture content of leaves when subjected to normal sunlight. It has been found that as the day advances the water-loss from such leaves is relatively decreased by the drying of the tissues, a process which would lead to wilting if continued. This phenomenon has been termed *incipient drying*, and it promises to become an important topic in plant physiology. The influence of sunshine upon water-loss has been quantitatively studied for a number of plants.

A study of the relations between the absorption of water and the general activities of the plant has been begun. It has been experimentally shown that the lower limit of available soil-moisture (commonly termed the wilting-point) is not the constant for a given soil plant that it has often been assumed to be, but that it depends primarily upon the evaporating power of the air.

Another factor upon which this supposed critical point depends has been experimentally shown to be the water retentivity of the soil. Dr. W. H. Brown, of the Michigan Agricultural College, very efficiently assisted in the experimental work along these lines during the summer of 1910. Prof. J. S. Caldwell, of the University of Nashville, has been employed as assistant in this work for the summer of 1911.

Studies on the relation of climatological conditions to the distribution of vegetation in the United States, a collaboration between Dr. Livingston and Dr. Shreve, have been in progress throughout the year. The discovery of several new methods for handling the existing climatological data, in order to arrive at approximate climatological descriptions of the various vegetational areas, has brought about delay in the preparation of the manuscripts and charts, but the work should be ready for publication in a short time.

The Influence of Atmospheric and Soil Conditions on the Transpiration, Water-content, and Anatomical Structure of the Palo Verde (Parkinsonia microphylla), by Mrs. Edith B. Shreve.

The daily curve of transpiration of young and full-grown trees at different seasons of the year has been found and compared with that of hothouse-grown young plants, record being kept of soil-moisture, humidity, air-temperature, evaporating power of the air (as measured by the porous-cup atmometer), leaf-temperature, and stomatal movement. Water-content determinations were made on young hothouse-grown plants, on outdoor seedlings, and on tips, branches, and trunks of trees, and the results are to be compared with the transpiration curve.

In connection with this work, methods have been developed for (1) measurement of transpiration of outdoor plants *in situ* under controlled conditions in shade and in sunshine; (2) measurement of leaf temperature; (3) preparation of the leaf as a whole for stomatal examination.

Chemical Effects of Radiant Energy in Plant Processes, by Dr. H. A. Spoehr.

Extensive experiments in photochemical reactions supposedly similar to those occurring in plants have been carried out in the Kent Chemical Laboratory of the University of Chicago during the past year. It has been found that aqueous solutions of potassium and calcium nitrates are reduced by means of ultra-violet light, sunlight, and even diffuse light, to the corresponding nitrites and ammonia, with the liberation of oxygen and the production of alkalinity in the solution. Schimper has shown that the disappearance of nitrates in the leaf takes place especially in the sunlight. If, therefore, the above reaction is actually the one taking place in the leaf, not only would the proper conditions for carbohydrate synthesis be established, but the nitrogen would also be produced in the best form and in the most available place for protein synthesis. That this is the actual fate of nitrates in the plant has not yet been proved, but it seems highly probable on theoretical grounds.

The production of an alkaline locus in the plant leaf has further importance, since from theoretical considerations it is highly probable that carbonic acid is reduced in the form of the potassium hydrogen salt in the early stages of photosynthesis.

The rôle of organic acids in the plant leaf and the relation of these substances to protein synthesis are under investigation. It has been found that the hydroxy-acids, under the influence of ultra-violet light, are decomposed, yielding CO_2 and aldehyde-like substances. These, of course, may be very important in the further synthesis of compounds of importance to the organisms. The effects in question may concern both photosynthesis as indicated and may also be associated with respiratory changes in the acids as discovered by Richards and described in another section of this report.

Some other remarkable reactions of organic substances under ultra-violet light will be discussed later.

The admirable conditions of sunlight at Tucson will be useful for the further study of these photochemical changes, and it is hoped also to devise some practical method of determining the phases of the energy of light which have special importance to vegetation.

Respiration in Cacti, by Prof. H. M. Richards.

The first step to be taken in an investigation of respiration in cacti was, of course, to obtain some definite knowledge of the acidity of the juices. It at once developed that there was a striking diurnal periodicity in the acid content of the sap and a series of determinations was undertaken to determine definitely the course and (in so far as possible at present) the causes of this regular variation. Of all the forms of cacti experimented with, *Opuntia versicolor* proved the most satisfactory and was chiefly employed, but the same general phenomena were observed in *Mamillaria grahami* and others.

In general the acidity curve in plants exposed to normal conditions of day and night was nearly the reverse of the diurnal temperature variation. The low point of acidity was reached at about 4 p. m., or slightly later than the maximum temperature, while the maximum of acid content, averaging twice and in some instances four times that of the minimum, occurred at about 5 a. m., when the temperature is nearly at its lowest. Other series of experiments made (kept wholly in the dark and at different and constant temperatures) showed an accumulation of acid at from 45° to 60° F., while at higher temperatures, ranging to 100° F., the characteristic lessening of acid was observed. On the other hand, plants exposed to full sunlight but kept cool, at a temperature not above 75° F., maintained during the whole course of the day the higher acidity of the early morning hours. Increased or diminished partial pressure of oxygen seemed to affect the results very little.

At the present state of the investigation it would seem, then, that temperature was the controlling external factor in this manifestation.

While the relation which this phenomenon bears to the respiratory functions of the tissues is unquestionably the most direct, and must be definitely determined by a careful comparison of an extended series of parallel observations, there should also be borne in mind the possible bearing of photosynthetic and anabolic processes on the question.

The Analysis of the Condition of Parasitism, by Dr. D. T. MacDougal.

The completion of the major experiments upon this subject and their description in Publication No. 141 left a number of parasitic arrangements in an active condition and these have been made the subject of some further analysis. In the earlier work the conclusion was reached that dependent nutritive couples were possible only between a host with a low osmotic pressure in the sap and an eligible parasite with a higher osmotic activity. Not all such pairs of plants might come into nutritive contact, however, and no explanation could be offered for the failure. Acidity was thought to be without influence in the matter. The estimations of acidity were made of material taken without regard to time of day and temperature. The recent researches of Richards have shown, however, that cacti contain twice as much acid in the morning as late in the afternoon. This changing acidity may exert a very important effect upon the absorptive capacity of the mucilages and other colloids, as well as upon the condition of the cell-walls. The analysis of this action may be expected to offer explanation of the remaining cases of xeno-parasitism which failed to survive.

FIELD OPERATIONS.

A large share of the problems under investigation by the members of the staff and associates require the examination of material in widely separated localities. A camp in charge of Prof. J. G. Brown, of the University of Arizona, was maintained at the plantations in the Santa Catalina Mountains in Arizona at elevations of 6,000 to 8,000 feet during June, July, and August, 1911. This camp served as a base for several members of the staff.

Early in the year a few series of observations were carried out from the Desert Laboratory in several directions along radii of 15 to 25 miles by motor transportation. The conditions of civil war in Mexico caused the cancellation of all plans for fieldwork to the southward in Sonora, as well as in the Delta of the Colorado River adjacent to the Salton Basin.

The Otero Basin of New Mexico was reached by rail, and in March a party followed a network of routes across it and the San Francisco Mountains. Both teams and motors were employed in this work. The great interior valley of California and an arm of the Mojave Desert were traversed in June; some travel in accordance with the method of previous years was made by boat and wagon on and around the Salton Lake in late summer.

The work of Dr. W. A. Cannon in Algeria carried him into regions in which the distributional features of desert vegetation have not hitherto been considered by botanists. Details are to be found in another section.

EQUIPMENT.

The structural additions to the facilities of the department include a plastered brick addition to the adobe laboratory to be used as an office for the Desert Laboratory, a concrete-lined stone reservoir of a capacity of 6,000 gallons for service to the shop, and experimental cultures and several cages and shelters for beetles and plants. Various articles of camping and packing outfit have been purchased. A heavy cart suitable for carrying material up the heavy grade of Tumamoc Hill has been secured. A motorcycle, originally purchased to be used by Dr. W. A. Cannon in the Algerian deserts, has been brought to Tucson and refitted for messenger use from the office. A 12-horsepower runabout which served the office has been used as part payment on a 20-horsepower motor, with which short field trips may be most expeditiously made to places within 20 miles of the laboratories. The larger machine is reserved for more serious expeditions with heavy equipment, and this vehicle has now carried parties one or more times over a region extending from Port Lobos on the Gulf of California in Sonora to San Francisco, over many stretches of country scarcely practicable for loaded wagons. A small tract of garden land has been acquired at Carmel for use in the acclimatization experiments, and it may be found advantageous to enlarge this by the purchase of an additional tract already in use. The apparatus and instrumental equipment of the laboratories has been enlarged only by conventional types and no new designs have been brought into use during the year.

Quarters and facilities for the photochemical work of Dr. H. A. Spoehr have been furnished from the regular equipment of the Kent Chemical Laboratory of the University of Chicago, by the courtesy of the officers of the chemical department of that institution. The greatest efficiency in dealing with some of the problems of photochemistry of direct importance in physiological research may be reached in localities offering the least interruption to daily exposure to sunlight and with adequate sources of power for controllable illumination. Some further experience will be necessary before plans for the final equipment may be made.

DEPARTMENT OF ECONOMICS AND SOCIOLOGY.*

Henry W. Farnam, Chairman.

No changes have been made during the past year in the staff of collaborators, and all are aiming to complete the work of their respective divisions at the earliest possible moment. Two have been especially handicapped by other demands upon them: Dr. Clark, who is still working for the Census Bureau in the Sandwich Islands, and Mr. Stone, who is managing his plantation in Dunleith, Mississippi; but both have given as much time as they could command to the work of the Carnegie Institution of Washington. Professor Gardner has obtained a leave of absence from academic duties for the year 1911–12, and Professor Willcox expects to obtain one for the year 1912–13, in order to secure time for the work of the Institution; Professor Willcox, Dr. Clark, Professor Meyer, Professor Johnson, Professor Commons, Mr. Stone, and the writer have begun the preparation of their final reports.

As explained in previous reports, the present organization of this Department is peculiar in that the work is conducted, not by scholars who receive a regular living salary to devote themselves to its interests, but by those who are already otherwise occupied, and can as a rule give but a part of their energies to the Department, in many cases taking no compensation for time spent, in others receiving but a small amount. This method has the advantage of economy, but the disadvantage that it is not easy to push the work, especially when the collaborators are in frequent demand for public and semi-public service. Thus, in the course of the past year, Dr. Clark has been engaged in census work, Professor Meyer has been appointed to the Interstate Commerce Commission, Professor Dewey has undertaken the editorship of the American Economic Review, and Professor Commons has accepted a position on the recently formed Wisconsin Industrial Commission.

Upon the death of Colonel Wright, in the spring of 1909, we were given clearly to understand that the current income of the Institution was already fully appropriated, and that we could not expect additional grants. We have therefore been using our best endeavors to bring the work to a conclusion under the appropriation originally made in December 1903.

We had on the first of September 1911 the following balances to our credit:

Administration Fund	$4,944.12
Index	17,911.02
General Research Fund	34,552.19
Total	57,407.33

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* Address, Yale University, New Haven, Connecticut. (For previous reports see Year Books Nos. 3–9.)

The balances of the twelve research divisions vary considerably, according to the magnitude of the subject to be treated and the rapidity with which the work has been conducted. Several of them have almost exhausted their appropriations; others have contracts outstanding which will absorb the greater part of their available funds; a few will probably be able to finish their work under the present grant; but it hardly seems possible that all of the work can be completed rapidly, unless we can pay at least several of the collaborators and some of their assistants a sufficient salary to enable them to take a leave of absence from their academic work, in order to devote themselves exclusively to the completion of their studies for the Carnegie Institution of Washington. In a number of cases (as in several mentioned by Mr. Parker in the report of his division) the assistants to whom elaborate pieces of work have been assigned have been obliged to devote all of their funds to the payment of subordinates and have had no compensation whatever for their own labor.

As the collaborators are in the habit of holding their annual meeting in October, we have had no general conference since a year ago, and the writer can not, therefore, present a definite budget; but from the best estimates that he can make, after consulting with individuals, he believes that with an additional appropriation of $25,000, to be spread out over two years, the work can be completed successfully, while without additional funds certain parts of it are sure to be much delayed and curtailed.

It should not be forgotten that the present series of contributions to the American Economic History is in the nature of preliminary work, as explained by the writer in a special report to the Executive Committee made April 18, 1910. The terms of the articles of incorporation of the Institution would seem to imply a Department of Economics and Sociology as one of its permanent divisions, whose importance and usefulness may be expected to grow with the increasing complexity of our economic and social life and the multiplication of our economic and social problems. A few of the possible lines of work were sketched in the special report referred to above. Such a department, when established on a permanent basis, should receive an annual grant of at least $25,000.

I respectfully request that, in making their plans for the future, the Trustees allow for an appropriation of $25,000 a year for a reorganized Department of Economics and Sociology and that in the meantime half of this amount, or $12,500, be made available for each of the years 1912 and 1913 in addition to the balance still undrawn of the original appropriation.

The following account of the work done during the past year is based upon reports of the heads of the several divisions.

DIVISION I.—POPULATION AND IMMIGRATION.

During the past year Mrs. Louise Seymour Houghton has published in the "Survey" parts of her study on the "Syrians in the United States" under the following titles and dates:

I. Sources and Settlement, July 1, 1911.
II. Business Activities, August 5, 1911.
III. Intellectual and Social Status, September 2, 1911.
IV. The Syrian as an American Citizen, October 7, 1911.

Professor Willcox has been at work with a secretary upon his final report. Regarding the prospects for the completion of this work, he says:

> I should say that this depends largely upon my obtaining a leave of absence for the academic year 1912–13, and spending it in writing the report. I sincerely hope and expect that that plan can be carried out, but beyond that I can not go at present. If it is, I should hope to have my report substantially finished by the end of that year.

DIVISION II.—AGRICULTURE AND FORESTRY.

President Kenyon L. Butterfield reports that the gentlemen in charge of the different sections of his subject are all making good progress, though in some cases they have been delayed by other calls upon their time. Of those who have made detailed statements, Prof. F. W. Blackmar, of the University of Kansas, reports that he has completed the parts relating to the "agriculture of the Indians and the early colonists," as well as that relating to cotton and tobacco, and has made progress with other sections.

Prof. H. C. Taylor, of the University of Wisconsin, has devoted the past summer to the monograph on "Land tenure in the United States," and hopes to complete it by the end of the present academic year. His work on the "History of agricultural production" has been delayed by the demands of the United States Census upon himself, Dr. Coulter, and Dr. Gray. The latter has, however, made good progress on his study of the plantations prior to the civil war, and his connection with the census has enabled him to gather much information during a three months' trip through the South.

DIVISION III.—MINING.

No publications have been made in this division during the past year. Reports by Dr. David T. Day on quicksilver, nickel, cobalt, platinum, etc., have been completed.

Reports which are still incomplete are those relating to iron ore, copper, the quarrying industry, and mining laws. Mr. E. W. Parker reports as follows regarding these subjects:

> *The iron-ore industry:* Prof. C. K. Leith, who has charge of the preparation of the history of iron-ore mining, has found, as the work developed, that it was a much larger field than was at first supposed, and that it was practically impossible to complete it within the original allotment of $1,000 or within the time first set for its completion. He and his assistant, Mr.

R. J. Holden, have devoted nearly all of their spare time to the work of this history. This is particularly true of Mr. Holden. I have had to increase the allotment of Professor Leith in order to have this work satisfactorily completed, as he had exhausted the amount of the original allotment without considering any compensation for himself or Mr. Holden. Professor Leith is hoping that he may be able to complete the work during the present calendar year.

The copper-mining industry: Mr. L. C. Graton has not been able to report much progress during the year, except that he has nearly completed some other work which had precedence over the work for the Institution. However, he has promise of securing an important mass of material on the history of the copper industry, which has already been prepared by Dr. James Douglas, that has never been published. Mr. Graton's work is in such shape that he has not been able to prepare a definite plan of treatment.

The quarrying industry: Mr. F. B. Laney reports that the work on the quarrying industry is fairly well done, the literature has been carefully canvassed, and an outline of the latter work has been made and some parts have been written. At the present time, however, there is little more than a lot of fairly well classified notes, which along some lines are reasonably complete, but along others are rather meager. The time which Mr. Laney has at his disposal is limited, and he advises me that he will be compelled to employ some clerical assistance. He tells me that with the help of a good assistant for two or three months during this winter he can deliver an official report by March 1912. To do this, however, will require some additional money, and I have promised Mr. Laney that, if possible to secure it, an additional allotment would be made to him. He will need at least $250 in order to complete the work. All the money that Mr. Laney has received so far has gone for actual expenses and for clerical help. He has not received any compensation on his own account.

Mining law: Mr. William E. Colby, of San Francisco, hopes to have his chapters on the history of the origin, growth, and development of mining law in the United States completed by the end of the present calendar year.

Division IV.—MANUFACTURES.

Dr. Victor S. Clark is still engaged in census work in the Hawaiian Islands, but has taken what time he could for the work of his division, having had his accumulated material shipped to Honolulu. He has been at work upon the first volume on manufactures, and he says regarding it:

> All the work done in this division has been done by me personally, and in my very limited morning hours before going to the office, and with frequent interruptions, one of them of nearly three months in Mexico and Cuba.

Division V.—TRANSPORTATION.

Prof. B. H. Meyer has employed as his assistant during the year Miss C. E. MacGill, and she has been engaged in digesting the material already collected. The work of the Interstate Commerce Commission required his attention during the winter, but he has been at work during the vacation upon the revision of his report. Professor Meyer writes:

I have spent considerable time this summer getting the manuscript for the first volume of the final report into shape. Much of it is practically ready. There are still several uncompleted essays for the second volume.

It is expected that all of these will be completed before the close of the year.

DIVISION VI.—DOMESTIC AND FOREIGN COMMERCE.

Prof. Emory R. Johnson makes the following report of the progress of the work of his division during the past year:

No works have been published during the year ending September 1911.

The "History of the foreign trade of the United States," written by Prof. S. S. Huebner and Dr. G. G. Huebner, is completed but not yet published. It is hoped that arrangements for its publication may be made during the ensuing year.

The "History of American coastwise commerce," by Assistant Prof. Thomas Conway, jr., is nearly completed. This is the last work assigned to collaborators, and it is hoped that this may be all ready for publication within a few months.

During the past year I have been giving some attention to the direction of the work done by collaborators and have outlined the final volume to be written by myself. One-third of this volume has been written and during the past year I have written two chapters. The pressure of my university duties and of certain expert work for the United States Government prevented me from giving as much time to the work of the Carnegie Institution as I had anticipated giving. It will be necessary for me to employ an assistant to help me during part of the next two years if I am to complete the work within that time, unless I should be able to secure a year's leave of absence from the university. That, however, I can not do on pay, and accordingly it will probably be necessary for me to employ assistants in writing the final volume.

DIVISION VII.—MONEY AND BANKING.

Prof. Davis R. Dewey has submitted the following report regarding the work of his division:

No monographs have been published since September 1, 1910. The following monographs have been received:

The free banks and the free-banking system of Indiana. By Charles B. Austin.
History of the national banking system. By Glover D. Hancock.

The following monographs are still unfinished:

Relation of the Treasury to the New York money market. By J. W. Crook.
Banking in Kentucky. By Elmer G. Griffith.
History of banking in Louisiana. By Theodore H. Jack.
Relation of the crop movement to the money market in the West. By F. L. McVey.
History of the greenback movement in Iowa and the Northwest. By C. C. Ruggles.
History of banking in Tennessee. By St. G. L. Sioussat.

I have made some progress during the past year in my own studies, and have the material now in shape so that I hope to be able to bring the work to completion within no long period. The greatest difficulty is in securing uninterrupted leisure in order to mass the material which has thus far been accumulated. I feel more confident in regard to finishing the work in a satisfactory form than ever before.

DIVISION VIII.—LABOR MOVEMENT.

Professor Commons has completed the publication of his "Documentary history of American industrial society," in eleven volumes, which contains a vast amount of material collected by him with the financial assistance of the Bureau of Industrial Research and of the Carnegie Institution of Washington. He has been lecturing on labor history during the past two years, and expects to continue the course during the coming year, though he has resigned his professorship in the University of Wisconsin in order to take up the work of the recently created Wisconsin Industrial Commission. He is employing, as his assistant, Mr. Selig Perlman, and is having monographs on a number of subjects prepared, as indicated in the following list:

Socialism and anarchism. By Selig Perlman.
Trade unionism from 1825–1837. By Helen L. Sumner.
Trade unionism from 1847–1863. By H. E. Hoagland.
Labor movement and land reform from 1835–1854. By John R. Commons.
The American Federation of Labor. By E. E. Witte.
The Knights of Labor. By David J. Saposs.
Hours of labor. By Lorian P. Jefferson.
The labor movement in California. By Ira B. Cross.

DIVISION IX.—INDUSTRIAL ORGANIZATION.

In accordance with the policy explained in previous reports, Prof. J. W. Jenks, in order not to duplicate material, is awaiting the completion of the work of some of the other divisions before resuming work on his own.

DIVISION X.—SOCIAL LEGISLATION.

Since the last annual report the following monograph has been handed in:

The land legislation of Texas. By Reuben McKitrick.

The following studies are still unfinished:

Anti-trust legislation of Wisconsin, Minnesota, Iowa, and Nebraska. By C. L. Waldron.
The labor legislation of Maryland. By H. Wirt Steele.
The labor and rural credit policy of the Southern States. By D. L. Peacock.

The writer has been engaged during the past year in work on the material already gathered by him, filling in numerous gaps by individual study, and with the aid of an assistant paid by himself. He has utilized part of the material in lectures delivered in the Graduate School of Yale University, and expects to further elaborate and, if possible, complete his study during the coming winter.

Division XI.—FEDERAL AND STATE FINANCE, INCLUDING TAXATION.

According to the report of Prof. Henry B. Gardner, the following publications have been made during the past year in this division:

The State debt of Ohio. By Prof. E. L. Bogart. Journal of Political Economy, April, May, and June 1911.
State finances of Texas during the civil war. By Mr. E. T. Miller. Texas State Historical Association Quarterly, vol. xiv, No. 1.
State finances of Texas during reconstruction. By Mr. E. T. Miller. Texas State Historical Association Quarterly, vol. xiv, No. 2.

The following monographs have been completed but not published:

The financial history of Connecticut (First Part). By Dr. Henry F. Walradt.
The financial history of Ohio. By Prof. E. L. Bogart. (Published in part in the Journal of Political Economy, see above.)
The financial history of Alabama. By Prof. William O. Scroggs.
The financial history of Oregon. By Prof. F. G. Young. (Completed.)

Professor Gardner furnishes the following list of studies still in progress.

Studies partially completed:

The financial history of California: By Prof. C. C. Plehn, University of California, Berkeley, California. He has the work well advanced, but does not promise completion at any definite time.

Comparative study of the financial development of certain of the larger cities of the country: By Mr. Oliver C. Lockhart, Ohio State University, Columbus, Ohio. A part of the work has been submitted, and considerable progress has been made. There were prospects that the work might be completed this fall, but Mr. Lockhart has been very ill this summer, and this will delay completion.

License taxes of Southern States: By Prof. H. A. Millis, Leland Stanford, Jr., University, California. Discontinued for the time being.

The financial history of Michigan: By Dr. Wilbur O. Hedrick, Michigan Agricultural College. Work well advanced towards completion.

The financial history of New Jersey: By Mr. Edgar Dawson, Normal College of the City of New York, Park avenue and Sixty-eighth street, New York. Interrupted by other work. No immediate prospect of completing it.

The financial history of Tennessee: By Prof. St. George L. Sioussat, University of the South. Will have the study completed by fall.

The financial history of Texas: By Mr. E. T. Miller, Instructor in the University of Texas. Extracts published under the titles, "The State finances of Texas during the civil war," and "The State finances of Texas during the reconstruction," in the Texas State Historical Association Quarterly, vol. xiv, Nos. 1 and 2. Expects to complete the work during the present year.

The financial history of Virginia: By Mr. Edgar Sydenstricker, formerly graduate student at the University of Chicago. Expects to submit the entire work in the near future.

The financial history of Connecticut: By Dr. Henry F. Walradt, graduate student at Yale University. Part I completed; hopes to complete Part II by the end of the calendar year.

Studies in active process of completion, but no part of which has been submitted:

The financial history of Illinois: By Mr. R. M. Haig, graduate student at the University of Illinois. Mr. Haig can get most of his material together by the fall, but is going to Columbia University, and has been granted an extension of time in order to write it up under Professor Seligman's direction.

The financial history of Minnesota: By Dr. R. V. Phelan, University of Minnesota. No definite time promised as date of completion.

The financial history of New York: By Mr. Don C. Sowers, graduate student at Columbia University. He hopes to complete the work by April 1912; has made substantial progress.

The financial history of North Carolina: By Prof. W. K. Boyd, Trinity College, Durham, North Carolina. He expects to submit part of the work in the winter.

The financial history of Pennsylvania: By Mr. Clyde L. King, graduate student at the University of Pennsylvania. He undertook work in April 1911 and has been getting it in hand this summer.

The financial history of South Carolina: By Mr. George McCutchen, University of South Carolina. No reply to recent letter.

Studies in which apparently little progress is being made:

The financial history of Indiana: By Prof. W. A. Rawles, Indiana University.

Prof. F. I. Herriott has given up his study of the financial history of Iowa.

Professor Gardner has secured a leave of absence for the academic year 1911–12, and hopes to utilize it for work on his final volume, though it is hardly expected that all of the monographs will be finished by that time.

Division XII.—THE NEGRO IN SLAVERY AND FREEDOM.

Mr. Alfred Holt Stone reports from Dunleith, Mississippi, that he has been at work upon his first volume, and expects to continue upon it during the winter. No monographs have been published or submitted in his division since last year, but the following are being prepared:

The economic transition from slavery to the free labor system. By Prof. W. L. Fleming.
The free negro in South Carolina. By Prof. Yates Snowden.

INDEX OF STATE DOCUMENTS.

Miss Adelaide R. Hasse makes the following report of her work on the Index of State Documents:

Work on the "Index of economic material in documents of the States of the United States" was unfortunately retarded during the past year, owing to the removal of the New York Public Library into its new building. Through the courtesy of the director of that institution, desk-room and the use of its collection of State documents are tendered the Department, as well as such services of the compiler as do not conflict with her duties as an employee of the library. For many months previous to the removal of the library, Miss Hasse was entirely occupied with preparations for the transfer of the Department under her charge. This explanation is made to account, in part, for the delay in the appearance of the Ohio index.

A further cause of delay was a change in the construction of the index. On the request of Miss Hasse, she was allowed to introduce, as an experiment, the personal names of authors of articles, reports, etc. Some progress had been made on the index before this additional feature was undertaken, the work already done having therefore to be gone over again. It is believed that this identification of the names of men such as Thomas Worthington, Peter Hitchcock, Alfred Kelly, Charles Reemelin, Charles Hammond, John Brough, John Klippart, and Norton S. Townshend with the several public services rendered by them, will add enough to the value of the index to have justified the delay referred to. A peculiar source of gratification connected with the Ohio index is the large number of early and unrecorded documents found by the compiler, as well as the recording of the unrecognized fact that for several years during the early fifties all of the State documents were printed in two editions. Of the 1850 report of the Department of Agriculture the compiler found five editions. All of these variants are carefully described in the index.

The volume to follow Ohio is Pennsylvania, fair progress on which has been made. Probably one of the completest available files of the Pennsylvania House and Senate Journals in German was destroyed in the burning of the State Library at Albany.

The following is a complete list of States published, with the year of publication:

California	1908	New Hampshire	1907
Delaware	1910	New York	1907
Illinois	1909	Rhode Island	1908
Kentucky	1910	Vermont	1907
Maine	1907	Ohio (in press).	
Massachusetts	1908		

DEPARTMENT OF EXPERIMENTAL EVOLUTION.*

C. B. Davenport, Director.

GENERAL STATEMENT OF RESULTS.

The principal developments of the year are (1) the initiation, at Cold Spring Harbor, in coöperation with this Department, of the Eugenics Record Office for the study of human heredity and the application of the laws of heredity to human affairs; (2) the discovery of the method of heredity of epilepsy in man, with clear indications of how it is reproduced and how its recurrence in later generations may be prevented; (3) the termination of Dr. Shull's work at Santa Rosa and the approach to completion of his book on Burbank's work; (4) the publication of Dr. Harris's statistical comparison of the fruits of *Staphylea* that develop with those that fail, showing the much greater symmetry of the former; (5) the publication of the researches of Dr. Frank E. Lutz, who bred fruit-flies for 43 generations, secured variations in the wing venation unlike anything known in nature in the group of Diptera (flies), found that despite long disuse of wing in these flies there was no evidence that this disuse affects their size, and discovered that when the flies are allowed to choose they tend to select normal consorts; (6) the discovery of two types of melanin and a clearer definition of the pigment-forming processes; (7) the publication of the demonstration by Castle in guinea-pigs and by myself in fowl of Guthrie's error in concluding that the germ-plasm is affected by the soma.

DETAILED REPORTS ON SCIENTIFIC WORK.

HEREDITY IN POULTRY.

Rumplessness.—Progress was made during the year in perfecting two strains of rumpless (tailless) fowl. These have been continued, not only to demonstrate their purity, but also to furnish material for the study that was begun last year by Miss Elizabeth S. Lum and continued by her during six weeks of the present summer. The study of the caudal vertebræ in a series of fowl, both with and without a uropygium, reveals a striking variation in their number. But in the rumpless fowl the number is invariably much smaller than in the tailed form and the bones are more or less fused together. The whole circulation and innervation of the region is rudimentary.

Control of the Form of Characters by Sex.—A special quantitative study is being made of various organs, such as the Y-comb and booting, to determine the degree to which their development is influenced by sex and in how far they differ in reciprocal crosses.

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* Situated at Cold Spring Harbor, Long Island, N. Y. Grant No. 676. $33,734 for investigations and maintenance during 1911. (For previous reports see Year Books Nos. 3-9.)

Heredity of Double Horn in Sheep.—A 4-horned ram presented by Mr. Alexander Graham Bell was used for the first time, both with two 4-horned ewes that he presented and also with other (even hornless) races. All males and all females showed to a striking degree the influence of the double horn, which appears to be dominant; *i. e.*, due to a special determiner.

Independence of Soma and Germ-plasm.—During the year the Director issued a paper entitled "The transplantation of ovaries in chickens." This paper gives the details concerning six experiments in which the ovaries were removed from each of two races of fowl and an exchange of the ovaries made from the body of one to the other. In opposition to the conclusions of Guthrie, it appeared first that the engrafted ovary did not enter into vital connection with the tissues of the host, but on the contrary became encysted. On the other hand, the tissue at the site of the removed ovary produced a new ovary by regeneration. It was shown that Guthrie's results are capable of the same interpretation. Therefore his results yielded no data as to the effect of the soma on the germ-plasm. It is proposed to extend the experiments with the aid of Mr. H. D. Goodale.

Reciprocal Crosses in Relation to Sex.—A series of experiments has been under way for several years on sex-limited characters in poultry. Some of these bring a confirmation from the breeding side of current cytological theories. Thus in a cross between a red-laced and a white-laced race, made reciprocally, it appears that all sons, in whichever way the cross is made, are white-laced, while daughters follow the sire in respect to the coloring of the lacing. This would indicate that the odd, or sex-differentiating, chromosome must, in poultry, be found in the female. Mr. H. D. Goodale, recently attached to this station, is extending researches into this subject, using ducks as well as fowl.

HEREDITY OF EPILEPSY IN MAN.

In connection with the Eugenics Record Office the Director coöperated with Dr. David F. Weeks, of the New Jersey State Village for Epileptics, in the study of over 200 families with one or more epileptics as children. The data concerning the families had been gathered with great care and at much expense by the field workers of the Eugenics Record Office and the State of New Jersey. Their studies of the product of certain selected human matings have much the value of experimental data. It appeared from this study that epilepsy behaves in inheritance as though it were due to the absence of some unit-character that makes for neural strength, and is an equivalent in inheritance of "feeble-mindedness." Thus if both parents are without the character that makes for neural strength, all of the children lack it; and if both parents, though neurally strong themselves, belong to weak strains, one-fourth of their children will be nervously undeveloped. The consideration of the pedigrees shows that in the families studied the proportion of mental defectives has in each of the last two generations been doubled from what it was in the preceding generation.

CONSANGUINEOUS MARRIAGE AND ITS EFFECTS.

During a vacation of ten days the Director visited a series of islands off the coast of Maine for the purpose of making a reconnaissance of a suitable locality for studies upon consanguineous marriage and its effects. Visits to both Hancock and Washington counties showed several places in which such consanguineous marriages are unusually frequent, chiefly on account of the barrier of water, and it is proposed, with the voluntary assistance of the people, to see in how far the results have or have not been deleterious. The study will be made by the Eugenics Record Office.

HEREDITY OF SEX IN A DIŒCIOUS HERMAPHRODITE PLANT.

Now that sex is generally regarded as controlled by a sex-determiner in the nucleus, the absence or presence of which results in one sex or the other, peculiar interest attaches to the behavior of sex-inheritance in a partially hermaphrodite species. Suitable material for this study is afforded by the cockle, *Lychnis*, and for several years past Dr. Shull has had about an acre of these plants under cultivation. This year his studies on *Lychnis* have dealt more particularly with the character of the vestigial organs of the one sex in individuals of the opposite sex, in order to learn to what degree the gap between each sex and the hermaphrodite condition is bridged by variations in the development of such vestiges. Only one individual in an aggregate of over 7,500 females and hermaphrodites permitted a doubt whether it should be classified as a female with exceptional development of staminodes or a hermaphrodite with aborted stamens. The gap between males and hermaphrodites is closed by the occurrence of every degree of development of female organs, from a minute bristle which is the usual condition in the male to a fully developed and functional ovary; but the number of these intergrading forms is very small relative to the number of normal males. Some evidence has been secured indicating that the eggs of the hermaphrodites may carry the hermaphrodite character, though heretofore hermaphroditism has seemed to be borne only by the sperms. A special series of crosses has been made to test this matter.

HEREDITY OF FLOWER COLORS.

Lychnis.—The study of the inheritance of the color of the flowers of *Lychnis* has been continued. The search for homozygous or pure-bred purple-flowered strains has been rewarded with success in the blue-flowered series, but not in the red. In the latter, failure has again resulted, because in each of the small number of crosses made for this purpose, one of the chosen parents proved to be heterozygous. A wild strain, known in Germany as *Melandrium rubrum,* has been found homozygous for the red color; but this form is not wholly satisfactory for experimental purposes, because of its fixed biennial habit. The effort to secure a homozygous red-flowered strain among the annual forms has therefore been continued. New features in the color-inheritance of *Lychnis* are the discovery of a "dominant white," which has given an F_1 mainly white-flowered when crossed with a homozygous red-flowered individual, and an all purple-flowered F_1 when crossed with a recessive white. A new Mendelian unit-character has been demonstrated by the unexpected appearance of a type of *Lychnis* having yellowish-green foliage, which is hypostatic to the full dark green of the usual type. Several sorts of variegation and several bud-sports are being investigated.

Poppies.—The problem of analyzing the hereditary factors which serve to differentiate the many garden derivatives of *Papaver rhœas* from each other and from their wild prototype has been resumed. The orange-red body-color of the petals in the wild form is epistatic to all the shades and tints displayed by the garden forms, but the presence of a distinct margin and of doubling often found in the cultivated strains are epistatic to the self-colored, single form of the wild poppy. Interesting phenomena of "repulsion" and inhibition of characters have been discovered and appropriate crosses have been made for further study.

AN ABERRANT INHERITANCE RATIO AND ITS INTERPRETATION.

On the principle of segregation of the determiners of characters, the characters should appear in the offspring of hybrids in certain definite ratios. An exceptional case appeared in breeding two kinds of shepherd's purse in the ratio of the two forms of seed-capsules and some leaf-characters that reappeared in the second hybrid generation. After several years of work Dr. Shull has reached a nearly complete explanation of the aberrant ratios, as follows: (*a*) There are two independent genes determining the triangular capsule, thus leading to the expected ratio 15:1 in the F_2 and both 15:1 and 3:1 in the F_3; (*b*) the *heegeri* individuals are less successful in the embryonic stages than the *bursa-pastoris* individuals, so that the ratio 15:1 becomes about 22:1, and 3:1 becomes 4.67:1; (*c*) that there is a variation in the relative potency of the genes determining certain features of the rosette-leaves which has led to the classification of a portion of the heterozygotes with the negative homozygotes. Further data are being sought bearing on these points.

THE INJURIOUS EFFECTS OF SELF-FERTILIZATION OF CORN.

Dr. Shull has continued his researches, which have revealed the great complexity of the population of any cornfield. Self-fertilization, as is well known, yields seed that develop into inferior individuals, while outcrossing usually gives vigor. Dr. Shull has been working on the hypothesis that the depauperate inbred strain represents a "pure line." If this is so, then cross-fertilization within the limits of the same pure-bred family ought not to result in the increased vigor that cross-fertilization at random does. Now, comparisons made between the effect of self-fertilization and crossing within the limits of the same pure-bred family and within the same F_1 showed in each case a very slight difference in favor of the crosses. This difference was so slight that the belief is entertained that it was due wholly to the fact that some of the families used were not yet completely homozygous, but there are other possibilities and these are being investigated. The F_1 hybrids between self-fertilized strains yielded on the average 68.07 bushels per acre as compared with only 44.62 bushels yielded by the corresponding F_2 families, a fact of great potential consequence to the practical grower. The conclusions derived from these investigations and published in 1908 have been still further strengthened by these results. These conclusions are (*a*) that the plants in an ordinary field of corn are generally very complex hybrids representing the combination of numerous elementary species or biotypes; (*b*) that none of these pure biotypes is sufficiently vigorous to be profitably grown in the pure state; (*c*) that the high physiological vigor of the ordinary maize-plant is the result of a stimulating effect produced by the union of unlike elements from the two parents; (*d*) that self-fertilization decreases the vigor by gradually reducing the strain to a pure-bred state, and not because there is any injury produced by self-fertilization or inbreeding *per se*. Comparisons are now being extended to the third and later generations, and tests are also being made to determine the effect of combining a number of different pure-bred strains into a single hybrid strain.

VARIATION AND MUTATION IN EVENING PRIMROSES.

Since the beginning of our work we have continued the studies of the evening primroses along the lines of Professor de Vries's work and with seed largely derived from his cultures. In the past year the particular directions of study, by Dr. Shull, have been the effects of cross and self fertilization. Families have been grown from seeds of a number of new forms which originated in the cultures of the preceding year. Some of these progenies have bred true to their new characters, others have split up into several types, and some have seemingly returned to typical *Oenothera lamarckiana*. Reciprocal crosses have been made among several biotypes of *O. cruciata*, and between each of these biotypes and *O. lamarckiana*.

THE THEORY OF PURE LINES.

This is quite the most hotly discussed of all topics in heredity to-day: Does selection proceed by the isolation of minute units or by shoving the character along a sliding scale? It is not clear whether there is any real contrast between these views, since if the steps of a flight be taken fine enough they will approach as close as possible to an inclined plane. Dr. Harris has been testing the pure-line theory by the use of beans—the same kind of plants that Johannsen used in his fundamental experiments. Many of Dr. Harris's records go back to 1905, and they afford excellent material for a critique of the pure-line theory. We may expect an early publication of these data.

QUANTITATIVE STUDIES OF SELECTIVE ELIMINATION.

An outline of these studies, which are being made by Dr. Harris, appeared in Year Book No. 9. Since that report it has been shown that the elimination of ovaries demonstrated in *Staphylea* is probably not due to the combination of such simple factors as a differentiation of the ovaries associated with their position on the inflorescence and a proportionally higher but random failure of the ovaries situated in the more distal regions of the inflorescence. It seems, therefore, that failure to develop must depend upon some innate unfitness with which definite structural peculiarities are associated.

Dr. Harris has instituted several studies to obtain further light upon these questions. Tests with other species are being made to determine whether the results found for *Staphylea* are at all general. Other criteria of functional unfitness are being sought. But the problem is so complex—involving so many factors which may often screen each other's influence—that it can not now be discussed in greater detail.

INFLUENCE OF BECOMING FERAL ON DEVELOPMENT OF THE NERVOUS SYSTEM OF A DOMESTIC ANIMAL.

The acquisition of Goose Island has permitted this Station to begin an important experiment on the changes that a domesticated species undergoes in becoming feral. Last year, as already reported, in coöperation with Prof. H. H. Donaldson and the Wistar Institute of Anatomy and Biology, an attempt was made to kill off the brown rats and to colonize the island with white rats (June 21, 1910). On July 21 of this year Dr. Hatai, of the Wistar Institute, visited the island, set two dozen spring traps, mostly along the western bank, where there are many holes. Not a single albino rat was caught, but, instead, 8 brown rats (*Mus novegicus*) of various sizes. Thirty-four albino rats, each having its ears marked for future identification, were then liberated on the island.

On July 17 Dr. Hatai and myself visited Goose Island to see if the albino rats had established themselves. Two female albinos with marked ears were found dead from severe wounds, as though bitten to death by rats. At this time, in broad daylight, no living albino rats appeared on the island; and this is the more noteworthy since the liberated rats were very tame. Dr. Hatai then set four traps, two along the western bank, where most of the Norway rats had been caught, and two behind the house at the southern end of the island.

Dr. Hatai reports:

Toward evening I saw one albino rat running swiftly in front of the house, picking up some particles of food which I had thrown out. Later I found several more albino rats running about at the back [south side] of the house. The next morning I found one albino rat, whose ears were marked, trapped at the back of the house, and one large female Norway rat along the bank. During the night I heard several times the screaming of the rats in front of the house, but could not determine which kinds of rats they were.

It now remains to be seen if the white rats can survive the winter on the Island.

ADJUSTMENT TO CAVE LIFE.

The subject of adjustment to darkness is one that requires a long period for its full elucidation. At the outset many special difficulties have had to be met and overcome. We have had the difficulty of carbon-dioxide in the water, of solution of lime from the concrete tanks, and of the growth of fungi in the darkness of the cave. The difficulty of carbon-dioxide in the water of the artesian well will require the construction of a settling basin containing growing plants. Such a basin will be advantageous also, inasmuch as it will form a natural breeding-spot for the small organisms that can be used by the cave fishes. Dr. Banta spent two months last winter in the cave region of southern Indiana collecting materials and working on problems connected with cave-life. In order that parallel experiments may be run with cave animals in the light, a vivarium was constructed at the north end of the main building to provide conditions like those of the artificial cave except for light. It is provided with hot water pipes for winter heating, and being on the north side of the building will be largely sheltered from the summer sun.

Already the amphibia reared in the cave have yielded interesting results. The tadpoles of *Amblystoma tigrinum,* the common salamander of our ponds, when reared in the light are black, but in the cave are "white" or nearly so. The light is necessary for the production of the body pigment in the developing tadpole.

A part of Dr. Banta's work is the light reactions of animals of which related species or individuals live in the cave and in the open. While in Indiana he worked on the light reactions of the amphipod *Eucrangonyx gracilis* of Mayfield's cave and on the outdoor forms of the same species that live abundantly in the surface streams of the same region. Studies have also been made on the feeding and breeding habits of *Asellus* and other invertebrates which it is desired to propagate in the cave.

The following non-cavernicolous species are now kept in the cave: *Hydra, Copepoda, Asellus communis, Oniscus asellus, Armadillidium vulgare, Porcellio scaber, Porcellio rathkei, Eucrangonyx gracilis* (surface form), *Gammarus fasciatus, Cambarus bartoni, Meta menardi* and other spiders, *Thysamma, Ceuthophilus, Planorbis, Limnea,* goldfish, sunfish, *Umbra limi,*

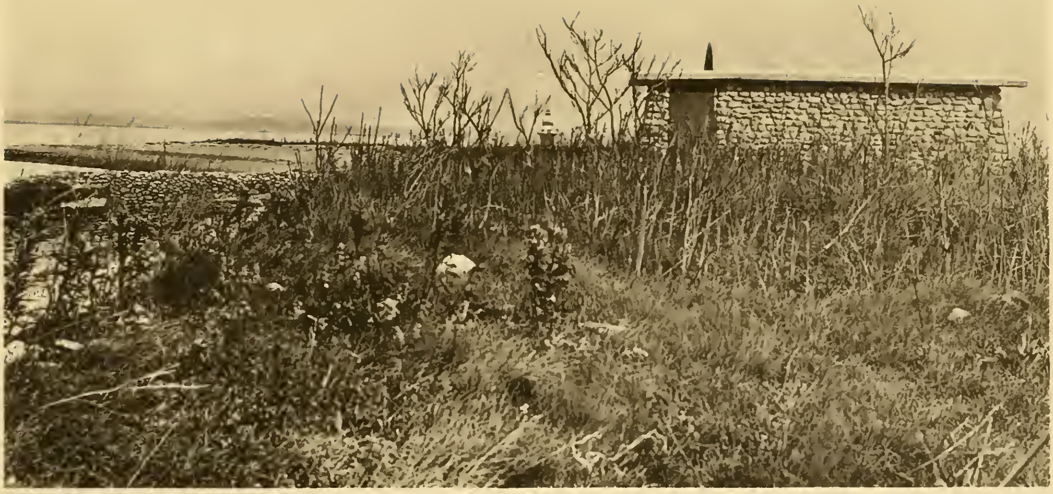

FIG. 1. Photograph taken on Goose Island, at its south end, looking northward through its long axis. Peck's Ledge lighthouse (from which fig. 2 was taken) is seen in the central background. In the foreground, right, is the shelter. At the left a wall can be seen running into the sea (low water). This is the south face of the 70-foot wharf. Sumach growing in foreground. Connecticut shore in the distance. Nov. 1911.

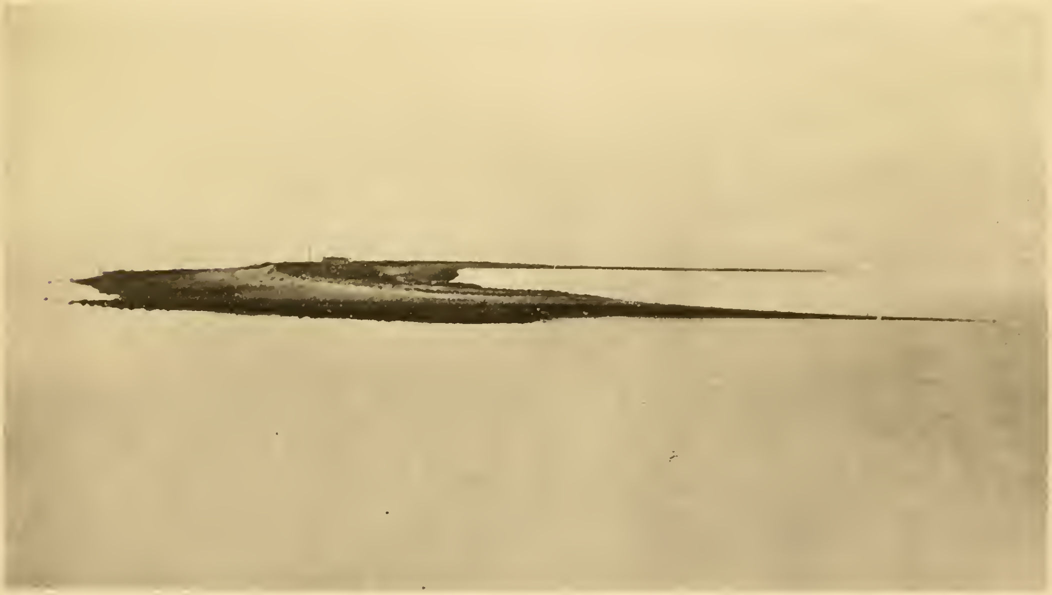

FIG. 2. Photograph of Goose Island, at low water, from lighthouse, looking south. Taken with rear combination of Zeiss VII*a* lens, giving telephoto effect. Shelter built by Mr. Dodge in center of island. The wharf lies on the Harbor side, on the right, between the two long bars.

Amblystoma tigrinum (larvæ), *Rana sylvatica* (larvæ) and other frog larvæ.

These cave forms are in daylight: *Cæcidotea stygia, Eucrangonyx gracilis, Cambarus pellucidus, Sinella cavernarum.*

RELATION BETWEEN THE HEREDITARY AND THE CHEMICAL ACTION OF PIGMENTS.

The studies of heredity of animal coloration quickly opened up questions upon which it seemed probable light could be thrown only by chemical studies. Accordingly a chemical laboratory was fitted up two years ago and Dr. R. A. Gortner put in charge of it. The first problem which he attacked was that of the melanins—their nature and behavior. To both these subjects he has made substantial contributions. He reports as follows:

The investigations as to the chemical nature of the animal pigments are as yet in a very preliminary state owing to the unusual difficulties in purifying these compounds. There appear to be two types of melanins, which are differentiated by their solubility or insolubility in dilute acids. Those melanins which are soluble in dilute acids are of a protein nature and do not appear as granules under the microscope, but rather they appear to be a part of the keratin structure and the coloration is diffuse as though the pigment were dissolved in the keratin. Such a pigment is found in auburn Caucasian hair.

The granular pigments are, apparently, insoluble in dilute acids and the nature of the molecule is still unknown. These melanins occur both alone (in negro hair, brown Caucasian hair, some black feathers, etc.) and in combination with the acid-soluble pigment or melano-protein (in black wool and horse hair).

In the study of these pigments there have been isolated 70 preparations, which are divided as follows:

	No. of preparations.		No. of preparations.
Black wool	35	Dominant white feathers	4
White wool	2	Light brown horse hair	5
Silky feathers	1	Dark brown horse hair	5
Black Minorca feathers	3	Brown Caucasian hair	6
Black rabbit hair	1	Auburn Caucasian hair	1
White rabbit hair	1	Other keratin structures	6

A considerable number of these preparations have been analyzed more or less completely, but much work is still necessary before the data can be correlated.

The formation of the animal pigments appears to be caused by an oxidation induced by the presence of an oxidizing enzyme. The origin of the pigment has been investigated in some of the insects: in the integuments of the meal worm (*Tenebrio molitor*), in the cuticula of the periodical cicada (*Tibicen septendecim*), and in the elytra of the Colorado potato beetle (*Leptinotarsa decemlineata*); the same general chemical reaction was found in each, and in every case there was an active oxidizing enzyme (tyrosinase) which acted upon some unknown chromogen and produced the pigmentation. It was found that the color-pattern in the elytra of the potato beetle is due to the localized secretion of the oxidizable chromogen.

STATISTICAL SUMMARY.

Poultry.—There were maintained 52 breeding-pens and 2,214 chicks were hatched. Further data were gathered on reciprocal crosses, sex control of characters, syndactyl and polydactyl, nailless, combless, horned, rumpless, and triple-combed strains. Selection experiments on plumage color were continued.

Finches.—These showed a return to normal fecundity and 65 young were reared from about 88 hatched.

Sheep and Goats.—Twenty-nine sheep and 2 goats were born. Important data on inheritance of the double-horned condition and on a new kind of coat color were gained.

Plants.—The range of species and number of individuals bred in Dr. Shull's experiments are shown in the following table:

Name of species.	No. of families.	No. of individuals.
Argemone hispida	1	6
Agrostemma githago	1	16
Bursa bursa pastoris	1	64
Bursa bursa pastoris × heegeri	24	4,709
Chrysanthemum leucanthemum	2	120
Eschscholtzia californica	1	33
Lactuca canadensis	5	252
Lychnis cœli-rosa	1	101
Lychnis coronaria	3	204
Lychnis dioica	176	12,127
Lychnis haageana	6	455
Lychnis noctiflora	1	7
Oenothera cruciata	4	420
Oenothera gigas	4	456
Oenothera lamarckiana	10	808
Oenothera lata	1	35
Oenothera nanella	1	177
Oenothera rubrinervis	6	1,607
Oenothera spp. and mutants	22	1,191
Papaver alpinun	2	119
Papaver bracteatum	2	213
Papaver commutatum	2	350
Papaver croceum	2	233
Papaver glaucum	2	100
Papaver nudicaule	1	50
Papaver orientale	3	304
Papaver pilosum	1	107
Papaver rhœas	66	8,618
Papaver somniferum	10	308
Papaver spp. and hybrids	8	333
Silene antirrhina	1	50
Silene vulgaris	1	85
Solanum guineense	1	50
Solanum guineense × villosum	1	50
Solanum nigrum	1	50
Solanum villosum	1	50
Tagetes lemmoni	1	21
Vaccaria vaccaria	1	18
Zea mays	111	6,751
Total	488	40,748

STAFF.

Miss Anne M. Lutz, who has been associated with our work from the beginning, first as secretary and later as cytologist, resigned in February and is continuing her studies on the cytological differences of the Oenotheras in Belgium. A full report of her prolonged studies here has been nearly completed.

Mr. Hubert Dana Goodale, formerly with Mr. B. B. Horton, at his experimental farm "Oakwood," Stamford, Connecticut, has been appointed to carry out various breeding experiments with poultry.

During the past summer Dr. Shull was ably assisted by Mr. Eugene E. Barker, who recorded data and made crosses, especially in maize and poppies.

CONSTRUCTION AND EQUIPMENT.

Since the last report of this Department there have been built at Goose Island a small shelter of stone in concrete and a stone pier. These were erected upon the suggestion of Mr. Cleveland H. Dodge, who also furnished the funds. The windows are barred with steel rods and the outer doors are of iron. The shelter is furnished with two cots, a few chairs, a collapsible boat, and a kitchen outfit, so that it can be used by one or two persons who need to spend the night. It was so used during the summer by Dr. Hatai. The pier is 70 feet long by 6 feet wide and is built of the stones of the outer beach, partly laid in cement.

A glass-covered extension on the north side of the main building was completed during the winter and spring. This affords a means of comparing the development of animals in the light and dark under otherwise similar conditions. Concrete tanks were installed on the floor of this extension.

For some time in the main building we have been crowded for room. It became absolutely necessary to have a building that could be used for chemical studies on mammals and for operating upon them, and it was finally decided to move all breeding animals to a new building, relieving the main building of the dirt that is inseparable from their culture and allowing expansion in it of the space available for records and their study. Plans were drawn by Mr. Robert W. Gardner, architect, for such a building, but from lack of funds a beginning has been made upon only a small portion. It is hoped that we may be able to complete the building during the coming year.

GEOPHYSICAL LABORATORY.*

ARTHUR L. DAY, DIRECTOR.

In view of the near approach of the tenth anniversary of the founding of the Carnegie Institution of Washington, it is appropriate to cast a retrospective glance over the plans originally projected for a geophysical laboratory and the results which have been achieved under those plans, the natural questions being: Has the work undertaken proved practicable? Do the results satisfy the demand which was made for a geophysical laboratory?

The first Year Book of the Institution contains two proposals for geophysical research: one by a joint committee of physicists and geologists, who considered the problem in a preliminary way at the request of the Trustees; the second, a definite project for a geophysical laboratory offered by Dr. G. F. Becker, of the U. S. Geological Survey. The two plans were very comprehensive, but were necessarily general in character and gave consideration to but few of the details which must be confronted in the working out of so extensive a project. Neither plan was adopted at that time.

During the following year, aided by an appropriation provided for that purpose by the Trustees of the Institution, a somewhat more detailed study of the project and of the geophysical problems which had been formulated by different geologists and physicists was undertaken by President Van Hise, of the University of Wisconsin, and by Dr. Becker. A group of leading American petrologists also devoted much thought to the general subject and to the details of attack in case geophysical research should be seriously taken up. The reports of these more detailed studies are contained in the second Year Book of the Institution, and to these we may now profitably look back for a moment if we would arrive at an opinion upon the practicability or success of geophysical research under the plan then proposed.

President Van Hise, in his examination of the field, sought specifically to ascertain "the nature of the problems which geologists regard as most pressing and which chemists and physicists regard as capable of being successfully attacked." The questions which to him appeared to offer promise of successful solution, he divides into four groups, as follows:

1. The relations of liquid and solid rocks.
2. Minerals and rocks from aqueous solutions.
3. The deformation of rocks.
4. The constants of rocks.

In the first class he mentions the following specific problems:

"They [the geologists] want to know the melting-points of rocks, the temperatures at which rocks crystallize from the magma, the relative specific gravities of melted and crystallized rocks, the effects of slow cooling upon the crystallization of rocks with and without pressure, the solution of one kind of rock in another, and, in short, all the phenomena which concern the transformation of magma to crystallized rock and crystallized rock to magma."

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* Situated in Washington, D. C. Grant No. 677. $54,480 for investigations and maintenance during 1911. (For previous reports see Year Books Nos. 3-9.)

We can perhaps best render an account of our stewardship by reviewing this group of problems as it appears from the laboratory viewpoint after the lapse of eight years.

It is first of all to be noted that the need of the geologists which is voiced by Professor Van Hise is all for measured facts and accurately defined relations, not for additional theories or mere indications. It obviously aims to make of geology an exact rather than a descriptive science. It is proposed to measure melting temperatures, crystallizing temperatures, specific gravities, conditions of equilibrium, pressures, and in general accurately to define the conditions surrounding rock formation exactly as the physicist and chemist have done in the development of their sciences, which now find universal application.

When such problems are placed in the hands of the research student who is familiar with the laboratory viewpoint, he at once goes to the heart of the matter with questions like these: Can apparatus be developed which will measure the temperature of liquid rocks without courting its own destruction? Can the rocks* themselves be chemically defined and separated into groups containing one mineral, two minerals, or three minerals each, and no others? Can the proposed pressures be applied at the temperatures where these rocks form? Will it prove practicable to measure specific gravities at extremely high temperatures; and, if so, what standards of comparison can be employed, etc.?

Although at that time none of these things had been very satisfactorily done, the tremendous possibilities of such research made it appear well worth while to risk much in an attempt to attain such powerful instruments of scientific investigation.

Without entering upon unnecessary detail, the attempt has now been made to control and measure the temperatures of rock formation with appropriate accuracy, to obtain (by making them in the chemical laboratory) rocks* which contain but one or two or three minerals and wholly free from the disturbing impurities commonly found in nature, to make accurate determinations of the density of these mineral and rock types, just before and just after crystallization, and finally, to experiment with such rock specimens under accurately measured pressures.

Furthermore, solutions have been formed of one mineral in another under conditions where all the minerals which crystallize out can be carefully studied. In cases where these crystals have proved minute in size, new methods of identification have been developed to enable us to meet that condition also. The effect of adding a third component to such a mixture of two has also been studied at all the temperatures where changes occur.

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*The word "rocks" is here used in a somewhat broader sense than the historic geological definition, but the meaning will be readily understood.

In a word, then, some essential phase of every one of the proposed problems in Group 1 has been undertaken and a sufficient number of such measurements made in each instance to demonstrate with convincing certainty the practicability of the general plan.

In a similar manner, though not to the same extent, the problems suggested under Group 2 (minerals and rocks from aqueous solutions) have been taken up and proved to be within the reach of laboratory resources, provided only that adequate time can be given to such studies. It happens that apparatus of a novel kind and difficult to build is required for such research, besides which the reactions themselves proceed with exasperating slowness.

The problems of Group 3 (the deformation of rocks) were undertaken in a separate plant in charge of Professor Adams, of Montreal, and are not properly included within this report.

Group 4 (the constants of rocks) has also been taken up in the Geophysical Laboratory to the extent of the facilities at its disposal. Temperatures, pressures, and densities have been studied, as already mentioned in connection with Group 1. Measurements of conductivity and of expansion coefficient have not yet been attempted upon actual rocks because of the fact that the plant thus far available did not include facilities for it; but there is not the slightest reason to believe that such measurements will prove as difficult as many of those already undertaken. Specific heat and the latent heat of fusion and inversion have been successfully measured for several typical minerals at the temperatures of rock formation.

The problems suggested by the distinguished group of petrologists (Adams, Cross, Iddings, Kemp, Lane, Pirsson, Washington, and Wolff, in Year Book No. 2) include all of those already mentioned, some others to which these are an indispensable preliminary, and some which are still beyond the reach of the present resources of chemistry and physics. Nine of these have been touched upon in the work of the Geophysical Laboratory hitherto.

Of chief interest in reviewing this work just at this time is perhaps the fact that no single problem of those so far attempted has miscarried. Although the resources of physics and chemistry have been severely strained to meet these extraordinary conditions offered by the igneous rocks, it has proved practicable to put the plan in operation and to test its productiveness over a considerable portion of the field which was mapped out.

The time involved in developing new methods and adapting old ones has been considerable, but that was to be expected.

In most cases there has been opportunity for the measurement of but a single typical substance or group of substances in order to elaborate and confirm the method of procedure and establish the conclusion. The broad application to minerals in general and rocks in all their multitudinous complexity still remains to be made, and is a herculean task for a single laboratory to undertake unaided. Our procedure has been mapped upon a kind of skeleton plan which has served to demonstrate the practicability of satisfactory studies of the minerals and rocks through reasonably complete measurements upon a few types, but it has not been able to include many applications to other mineral or rock species, even when nearly related to the type studied, or to exhaust the possibilities of any portion of the field. Such studies must await a coöperative effort among the university or other laboratories interested, and some extension of existing facilities. The success of such studies, whenever and wherever they may be undertaken, is already assured.

It seems a proper time to call attention to another branch of activity upon which considerable emphasis was laid by the joint committee of distinguished physicists and geologists whose report is contained in the first Year Book of the Institution. I refer to the study of vulcanism by direct application of laboratory (quantitative) relations and methods. This problem was also one of three specially designated by Dr. Becker in his project for geophysical research, which is contained in Year Book No. 1. In the development of geophysical research in the laboratory since that time, it has seemed wise to postpone the serious consideration of so broad and important a subject until the methods and equipment should be developed to a point where such consideration might be expected to yield something more than mere speculation. During the past year, however, an opportunity was afforded the Laboratory to make a preliminary study of an active volcano. The occasion was an expedition organized by Professor Jaggar, of the Massachusetts Institute of Technology, to visit the active crater of Kilauea, in the Territory of Hawaii, one purpose of which was to stretch a cable across the crater and to make an accurate measurement, for the first time in the history of volcanic study, of the temperature in the middle of the active lava basin. The Laboratory was invited to make plans for appropriate apparatus for measuring this temperature, and to send a representative to carry out the measurements at the crater. The invitation was accepted, and in pursuance thereof specially designed apparatus was built, tested, and Mr. Shepherd, of this Laboratory, spent two months of the past summer measuring the temperature in the midst of a boiling lava basin 1,000 feet or more in diameter. Of the result it may be said that although three sets of apparatus were destroyed by the lava, an accurate measurement of the temperature in the most active portion of the crater was obtained. The temperature was 1000° C.

The participation of the Laboratory in the enterprise projected by the Massachusetts Institute of Technology ends with the successful accomplishment of the work for which it assumed the responsibility, and nothing further need be said of it in this place. But it afforded an opportunity for a member of our own staff, experienced in the laboratory study of the relations of the minerals, to examine into the character of the problems offered by an active volcano and the possibility of offering a positive answer, through laboratory study, to some of the vital questions about the formation of the earth.

Without entering too intimately upon details, the result of this preliminary examination makes it appear entirely practicable to learn something of the sources of volcanic energy through laboratory study of the reactions going on in an active crater.

THE PUBLISHED WORK OF THE YEAR.

The results of the laboratory work of the year just past are contained in the following reviews of the papers published by members of the laboratory staff:

(1) Preliminary report on the ternary system $CaO–Al_2O_3–SiO_2$. A study of the constitution of Portland cement clinker. E. S. Shepherd and G. A. Rankin. With optical study by Fred. E. Wright. J. Ind. Eng. Chem., 3, 1. 1911.

Two earlier papers from this Laboratory* having prepared the way for a systematic study of the ternary systems, the present paper presents the results thus far obtained with the interesting oxides, lime, silica, and alumina.

In the earlier work with mixtures of pure lime and silica, two compounds, the metasilicate ($CaO.SiO_2$) and the orthosilicate ($2CaO.SiO_2$), were definitely established, but no trace of the hitherto generally accepted tricalcic silicate ($3CaO.SiO_2$) could be found in mixtures of pure lime and pure silica. In the three-component system, on the other hand, the tricalcic silicate appears promptly with the addition of alumina to mixtures of appropriate lime-silica concentration, and after a long and difficult experimental investigation, involving the study of about 1,000 heat treatments of various compositions, many of which required to be studied at temperatures between 1800° and 1900° C., it has finally been prepared pure, excepting for a small excess (between 1 and 2 per cent) of orthosilicate or lime or both.

Tricalcic silicate appears to be unstable at its melting temperature, and so does not form from a melt of this composition. For the same reason, it does not form eutectics with the adjacent compounds, calcium orthosilicate and lime. Neither is there any evidence that the tricalcic silicate takes up calcium orthosilicate or lime in solid solution.

In addition to the tricalcic silicate, a new and probably unstable form of the orthosilicate has been discovered which may prove to be of importance in Portland cement.

The general boundaries of the different phases occurring throughout the entire diagram (for diagram cf. original paper) of the ternary system $CaO–Al_2O_3–SiO_2$, have been established, together with the course of the boundary curves. From these it is possible to predict the compounds which will crystallize out of a lime-silica-alumina cement of any composition, provided only that the compounds are intimately mixed and the heat is sufficient to bring the mixture to equilibrium during formation. The exact location of the quintuple points, with the exception of points 13 to 17 and the isotherms, remains to be established. The location of these quintuple points is as follows:

Point.	17.	16.	15.	14.	13.
CaO	59.5	58.5	52.8	49.2	48.5
Al_2O_3	32.5	33.0	40.5	44.0	42.0
SiO_2	8.0	8.5	6.7	6.8	9.5

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* "The lime-silica series of minerals." Arthur L. Day, E. S. Shepherd, and F. E. Wright. Am. J. Sci. (4), 22, 265 (1906). "The binary systems of alumina with silica, lime, and magnesia." E. S. Shepherd, G. A. Rankin, and F. E. Wright. Am. J. Sci. (4), 28, 293 (1909).

Portland-cement clinker within the concentration limits set by Richardson, *when in equilibrium,* may exist in the following combinations, depending primarily upon relatively small changes in the quantity of lime present:

I.	II.	III.	IV.	V.
CaO.	$3CaO.SiO_2$.	$2CaO.SiO_2$	$2CaO.SiO_2$.	$2CaO.SiO_2$.
$3CaO.SiO_2$.	$2CaO.SiO_2$.	$3CaO.Al_2O_3$.	$5CaO.3Al_2O_3$.	$2CaO.Al_2O_3.SiO_2$.
$3CaO.Al_2O_3$.	$3CaO.Al_2O_3$.	$5CaO.3Al_2O_3$.	$CaO.Al_2O_3$.	$CaO.Al_2O_3$.

Richardson's typical cement corresponds to class II. The relative cement-forming value of the above mixtures has yet to be determined. The more intimate the mixture of the raw material, and the more uniform the heat treatment, the closer will be the approach to equilibrium and therefore to constant relations and the more uniform the behavior of the final product. Classes III and IV are predicted from the general direction of the boundary curves and the quintuple points 14 and 15 (cf. diagram). Class V will occur in cements low in lime and will differ only in the relative amounts of the different phases from pure slag cements whose compositions lie below the line joining the calcium orthosilicate and $2CaO.Al_2O_3.SiO_2$ compositions. Type V is dependent on the nature and location of point 13 and is to be regarded as tentative.

If solid solutions are formed they are very limited in extent and are not sufficient to affect the optical properties of either silicate, the lime or the aluminate. This fact serves to give greater definiteness to the problem and an unexpectedly clear field for studies of the cement-forming quality of clinkers of nearly related composition but different chemical constitution. It therefore seems inevitable that such studies will lead to more reliable standards in cement practice.

The diagram indicates that the constitution of slag cement will be seriously affected by relatively small differences of composition in the neighborhood of the line joining the compounds calcium orthosilicate and $2CaO.Al_2O_3.SiO_2$. It is, however, unwise to draw positive conclusions about the character of this portion of the diagram until it has been more carefully studied.

Incidentally, it has been observed that Fe_2O_3 appears *not* to form solid solutions with CaO, $2CaO.SiO_2$, or $3CaO.Al_2O_3$. It does appear to react in some way with $5CaO.3Al_2O_3$, but the nature of this reaction has not yet been studied. Attention should also be called in passing to the important fact that Fe_2O_3 dissociates at about 1400° with the formation of Fe_3O_4—a fact which seems to have been overlooked by some investigators.

Finally, too great importance can not be given to the constant use of the microscope in cement study and practice. It is not improbable that microscopic examination will eventually provide much of the information desired about the constitution of test samples, with the advantage over chemical methods of giving immediate results.

It remains to determine the isotherms of the diagram and to determine whether or not the five typical "clinkers" possess any differences in properties when hydrated to form cement. The work on the isotherms is well under way.

(2) Recent investigations into the nature of cement at the Geophysical Laboratory, Carnegie Institution of Washington. E. S. Shepherd. Eng. News, 65, 350. 1911.

A briefer presentation of No. 1 above for the use of engineers.

(3) Die Rolle des Wassers im Tremolit und gewissen anderen Mineralien. E. T. Allen und J. K. Clement. Z. anorg. Chem. 68, 317. 1910.

A German translation of "The rôle of water in tremolite and certain other minerals" (Am. J. Sci. (4) 26, 101, 1908). Reviewed in Year Book No. 7, p. 101.

(4) Quarz als geologisches Thermometer. Fred. Eugene Wright und Esper S. Larsen. Z. anorg. Chem. 68, 338. 1910.

A German translation of "Quartz as a geologic thermometer" (Am. J. Sci. (4), 27, 421, 1909). Reviewed in Year Book No. 8, p. 103.

(5) Die binären Systeme von Tonerde mit Kieselsäure, Kalk, und Magnesia. E. S. Shepherd und G. A. Rankin; nebst optischen Untersuchungen von Fred. Eugene Wright. Z. anorg. Chem. 68, 370. 1910.

A German translation of "The binary systems of alumina with silica, lime, and magnesia" (Am. J. Sci. (4), 28, 293, 1909). In this translation certain minor changes have been made in the text in consequence of later experimental work and all temperatures are expressed in terms of the new Day and Sosman high-temperature scale (1910). The original paper is reviewed in Year Book No. 8, p. 104, the temperature scale in Year Book No. 9, p. 93.

(6) Die genaue Bestimmung von Schwefel in Pyrit und Markasit. E. T. Allen und John Johnston. Z. anorg. Chem. 69, 102. 1910.

A German translation of "The exact determination of sulphur in pyrite and marcasite" (J. Ind. Eng. Chem., 2, 1, 1910). Reviewed in Year Book No. 9, p. 97.

(7) The transmission of light through transparent inactive crystal plates, with special reference to observations in convergent polarized light. Fred. Eugene Wright. Am. J. Sci. (4), 31, 157. 1911.

Reviewed in Year Book No. 9, p. 100.

(8) Schmelzpunktsbestimmungen. Walter P. White. Z. anorg. Chem. 69, 305. 1911.

A German translation of "Melting-point determination" (Am. J. Sci. (4) 28, 453, 1909). Reviewed in Year Book No. 8, p. 106.

(9) Schmelzpunktsmethoden bei hohen Temperaturen. Walter P. White. Z. anorg. Chem. 69, 331. 1911.

A German translation of "Melting-point methods at high temperatures" (Am. J. Sci. (4), 28, 474, 1909). Reviewed in Year Book No. 8, p. 104.

(10) The melting points of minerals in the light of recent investigations on the gas thermometer. Arthur L. Day and Robert B. Sosman. Am. J. Sci. (4) 31, 341. 1911.

When the work of the Geophysical Laboratory was begun, no temperatures above 1150° C. had ever been accurately measured with the nitrogen thermometer. It had been the custom of the Reichsanstalt to interpret the readings of a thermo-element above 1150° by first calculating the curve of temperature and thermal electromotive force of the element for the region between 400° and 1150°, and then extrapolating this curve. The fixed temperatures commonly printed on high-temperature measuring devices, like the Siemens and Halske direct-reading galvanometers, are based on this extrapolation.

The absolute accuracy of the Reichsanstalt scale (400° to 1150°) was estimated to be about 3° at 1150°, and the extrapolation above 1150° with the thermo-element is certainly in error by more than ten times this amount at the melting-point of platinum. It was therefore deemed necessary to undertake a new investigation of the high-temperature region with the gas thermometer, and in particular to extend its range for a considerable interval above 1150°, in order that a sound basis might be established for the mineral work of this laboratory.

Accordingly, such an investigation was begun in 1904, and the final results were published within the past year.* It proved possible not only to attain higher accuracy in the region between 400° and 1150°, but to extend the fundamental measurements to 1550°, with an accuracy estimated at 2° at the latter temperature.

In the meantime, the temperature measurements made in this laboratory with thermo-elements had been interpreted in the old way, by extrapolating the curve of temperature and thermal electromotive force. These results now require to be corrected by the amount of the difference between the old temperature scale and the new, which makes it necessary to recalculate the existing temperature data of this laboratory in terms of the new scale. This paper presents a summary of the values resulting from this recalculation.

Some of the European students of silicate solutions have encountered difficulties in the determination of mineral melting-points which have led to the belief that most or perhaps all minerals do not melt at a determinable "point," but rather that the phenomena of melting extend through a considerable temperature interval. Experimental evidence is here offered, in the case of two of the typical minerals in question, that this uncertainty was merely the result of the experimental method employed. This is a matter of some importance, because the above conclusion, if true, would necessitate a new system of definitions for melting silicates.

(11) Ein neues petrographisches Mikroskop. Fred. Eugene Wright. Tschermak's Min. Pet. Mitt. 29, 489. 1910.

A German translation of "A new petrographic microscope" (Am. J. Sci. (4) 29, 407, 1910). Reviewed in Year Book No. 9, p. 95.

(12) The influence of pressure on the melting points of certain metals. John Johnston and L. H. Adams. Am. J. Sci. (4) 31, 501. 1911.

The authors have been engaged in developing methods and apparatus by means of which it will be possible to investigate the effects of high temperatures and pressures on certain systems and reactions, and especially those in which water plays an important part. The work has progressed until now we are able to introduce into the bomb current leads and thermo-element wires in such a manner that the wires are all thoroughly insulated electrically, and the joint remains absolutely pressure-tight. Thus, it is possible to heat a substance to somewhat over 400°, under pressures up to 2,000 atmospheres, and to measure both temperature and pressure with precision. Moreover, the whole system, by reason of the special methods of construction adopted, is absolutely free from pressure leaks, even when the bomb is repeatedly closed and opened, disconnected from, and reconnected with, the remainder of the high-pressure system. For instance, on one occasion heating was continued for 30 hours continuously at a pressure of 1800 atmospheres, without sensible loss of pressure in the whole interval.

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* Day and Clement, Am. J. Sci. (4) 26, 405, 1908; Day and Sosman, Am J. Sci. (4) 29, 93. 1910. R. B. Sosman, Am. J. Sci. (4) 30, 1. 1910.

With this apparatus, the melting-points of tin, bismuth, cadmium, and lead were determined, first at atmospheric pressure, and afterward with a gradual increase of the pressure up to 2,000 atmospheres. The change of melting temperature with pressure was found to be an accurately linear function of the pressure.

By substitution in the Clausius-Clapeyron equation of the data of Vicentini and Omodei on the volume-change at the melting-point, and of Person on the latent heat of fusion, dt/dp was calculated for each of the four metals. The calculated values are in satisfactory agreement with those observed. Incidentally, a convenient standard curve for the calibration of copper constantan thermo-elements at temperatures from 0 to 425° has also been computed and included in the paper.

(13) The phenomenon of occlusion in precipitates of barium sudfate and its relation to the exact determination of sulfate. John Johnston and L. H. Adams. J. Am. Chem. Soc., 33, 829. 1911.

The occlusion by barium sulphate of other sulphates is a general phenomenon. The amount of this occlusion depends upon (*a*) the composition of the original solution; (*b*) the fineness of the precipitate, which in turn is conditioned by the degree of solubility of barium sulphate in the particular medium, the rate of precipitation, and the time and manner of standing between precipitation and filtration. The phenomenon is therefore in all probability an absorption at the surface of the grains of the precipitate, since it is affected by the factors just mentioned.

On the basis of the knowledge gained in this way, attempts were made to find a direct method for the determination of sulphate which should be generally applicable, exact, and require only small and easily determined corrections. The following procedure is suggested: To the solution (300 c.c. for a precipitate to weigh 2 grams) add 50 c.c. of concentrated hydrochloric acid, heat to boiling, and precipitate, stirring constantly, with a 10 per cent solution of barium chloride. This should be added at such a rate that about four minutes is required in running in the 22 c.c. necessary; the rate is best regulated by attaching a suitable capillary tip to the burette containing the barium chloride solution. Evaporate the whole to dryness on the steam-bath (this may be done immediately after precipitation), take up with hot water, filter through paper, wash until the washings are free from chloride, ignite very carefully (so as to obviate reduction), and heat to constant weight over a Bunsen burner. The necessary correction is determined by a concurrent calibration of the method; that is, by dissolving an equivalent weighed amount of pure dry sodium (or potassium) sulphate in a medium such that the resulting solution is as nearly as may be of the same composition as the solution to be analyzed; the sulphate in this comparison solution is then determined precisely as above. The difference between the calculated amount of barium sulphate and that actually found is the correction to be applied to the weight of the precipitate obtained in the actual analysis.

This procedure, as compared with that advocated by Allen and Johnston, is easier and much more rapid; it is, however, not so generally applicable, but may be used whenever the composition of the solution containing the sulphate to be determined is known approximately; and, we believe, will yield results, accurate to ± 0.05 per cent of the total sulphate present, in most cases likely to occur in general analytical work.

(14) Vorläufiger Bericht über das ternäre System $CaO–Al_2O_3–SiO_2$. Eine Untersuchung über die Konstitution der Portlandzement Klinker. E. S. Shepherd und G. A. Rankin; nebst optischen Untersuchungen von Fred. E. Wright. Z. anorg. Chem. 71, 19. 1911.

A German translation of the "Preliminary report on the ternary system $CaO–Al_2O_3–SiO_2$. A study of the constitution of Portland cement clinker" (Jour. Ind. Eng. Chem., 3, 1, 1911). Reviewed under No. 1 above (p. 92).

(15) Recent advances in high-temperature gas thermometry. Arthur L. Day. Trans. Faraday Soc. London. Vol. VII, 1911.

An address before the Faraday Society of London, reviewing the more important features of the recent work with the gas thermometer conducted at this laboratory. This work is briefly described under No. 20 (p. 99).

(16) Die Untersuchung von Silikaten. Arthur L. Day. Z. Elektrochem., 17, 609. 1911.

An address given at the annual convocation of the Bunsen Gesellschaft, held at Kiel, Germany, reviewing some of the more interesting phases in the laboratory investigation of silicates compared with some of the more familiar fields of physico-chemical research.

(17) The detection of small heat effects at high temperatures. (Abstract.) Walter P. White. Phys. Rev., 32, 604. 1911.

In calorimetric work at ordinary temperatures, stirring is generally necessary to equalize temperatures. Although the need for it is enormously greater in the hot electric furnace, where the surrounding temperature differences are much greater, and convection and radiation are far more active, the difficulty of providing for stirring by means of the few materials available at high temperatures is so great that stirring has almost never been tried, and observers have been satisfied to do as well as they could with the uneven temperatures which prevailed in its absence. This has been made easier because the work done has dealt largely with melting-points, where quantitative measurement of heat is not required. Although the results are far less perfect than can be obtained at low temperatures, they have generally proved sufficient for the purpose in view. Some experimenters, however, have applied the melting-point arrangements to the quantitative determination of heat effects, even claiming more than 1 per cent accuracy. Others, on the contrary, have shown a disposition to reject almost all evidence as to heat quantity based on observations made with the electric furnace. A fair opinion seems to lie between these two views. Determinations in the electric furnace usually show an almost surprising reproducibility, which tends strongly to convey a false impression of accuracy. Large systematic errors, however, are usually present, especially where only one or two thermoelements are used, since the temperature at any given point affords a very imperfect indication of the average value of the temperature in either furnace or charge, while the distribution in both is liable to change both with time and with temperature. It follows, then, that where reproducibility is the main essential, results of high accuracy can often be obtained, but for absolute results the very greatest patience and thoroughness are needed in varying the conditions and otherwise eliminating possible systematic errors.

In the detection of slight heat effects, high absolute accuracy is not expected. Hence, in this direction relatively great success can be obtained.

The general principle of the method is simple and fairly familiar. No moving bodies are present, and changes in the temperature of the charge are brought about solely by changing the furnace temperature. The heat effects in the charge are inferred from the changes in its temperature. The temperature of the charge thus depends upon two things: first, the furnace temperature, and second, the heat effects in the charge. The manipulation consists (after the furnace is once loaded) in observing (usually once a minute) the temperature rise, regulating the furnace current accordingly, and observing, either directly or indirectly, the temperature difference of furnace and charge.

The interpretation of the results may, in theory, be made very simple.

The temperature gradient, *G*, between charge and furnace, serves as the measure of heat-flow to the charge. The flow actually is proportional to *G*, and to the heat-transmittance, *F*, of the space between furnace and charge. The exact values of both *G* and *F* are usually unknown, and, as already stated, may vary with time, temperature, rate of heating, etc., so that accurate heat determinations by means of them, though possible, are more difficult than has sometimes been realized. But in the *detection* of a small heat effect we have merely to determine the change in *G* caused by the addition of the effect to the heat which is required to change the temperature of the charge. For instance, a silicate charge (2 grams) of specific heat 0.3, heated 10° per minute, lagged 3° behind the furnace ($G = 3°$). Hence 3° in *G* corresponds to 3 calories per minute. If an inversion absorbing 3 calories and extending over 100° should occur, *G* would be increased 0.1, or 0.3° for 10 minutes; if the inversion should take place in one minute, *G* would be doubled, or increased 3°, etc. The detection of small heat-effects is easier: (1) The larger *G* is, per calorie per minute, (2) the freer *G* is from other variations, (3) the quicker the inversion occurs; it is only sluggish inversions whose detection gives any trouble.

G increases with the furnace-rate; hence a rapid rate is of the first importance. *G* also increases with the diameter of the charge, but can be made steadier in the case of a small charge, and the advantage of the small charge appears to be greater on the whole. Fluctuations in the furnace rate cause variations in *G;* these are partly eliminated by measuring *G*, not between charge and furnace, but between the charge and another body ("neutral body" or "dead body") closely resembling it. For the best results the other body is used, and the furnace is regulated as carefully as possible, besides. Runs are also made with both bodies alike, to eliminate effects due to the thermo-elements or to the lack of symmetry between the two bodies, and, of course, repetitions eliminate accidental irregularities. The apparatus now used is small, two platinum crucibles holding 1 c.c. each, 3 mm. apart, and surrounded by a wider porcelain tube to increase uniformity of temperature. A differential thermo-element is also used, which gives directly the temperature difference of the two bodies at any instant. This not only increases accuracy, but saves much tedious computation, necessary when the temperatures are read separately. A complete platinum inclosure shields the whole system from leakage currents out of the furnace-coil. In one set of determinations made on different days with the same set-up, conditions were reproduced over a 300° interval with a maximum variation of from 0.03° to 0.06° in the different determinations. This was with a silicate charge and indicates that 1 calorie distributed over 100° could often be detected. But this would be a more difficult case than has yet been found in practice. In one case it was observed that the first heating in each day, which, of course, occurred immediately after the furnace had been cold, gave results differing by 0.3° from later heatings, although the furnace was cooled 300° between all the heatings. This condition reproduced itself at 0.1° on successive days and could, therefore, be largely eliminated, but might prove decidedly deceptive if overlooked, and if the heat effect was, as often happens, one occurring only in the first heating. This circumstance well illustrates the care which must be taken to avoid systematic errors in this kind of work, and the danger of assuming too hastily that the precautions in this direction have been sufficient.

(18) Die Schmelzpunkte der Mineralien im Lichte neurer Untersuchungen über das Gasthermometer. Arthur L. Day und Robert B. Sosman. Z. anorg. Chem. 72, 1. 1911.

A German translation of "The melting-points of minerals in the light of recent investigations on the gas thermometer" (Am. J. Sci. (4), 31, 341, 1911). Reviewed under No. 10 (p. 94).

(19) Der Einfluss des Druckes auf die Schmelzpunkte einiger Metalle. John Johnston und L. H. Adams. Z. anorg. Chem. 72, 11. 1911.

A German translation of "The influence of pressure on the melting-points of certain metals" (Am. J. Sci. (4), 31, 501, 1911). Reviewed under No. 12 (p. 95).

(20) High-temperature gas thermometry. Arthur L. Day and Robert B. Sosman. With an investigation of the metals by E. T. Allen. Publication No. 157, Carnegie Institution of Washington.

It is now something over five years since the Geophysical Laboratory took up the task of redetermining the absolute temperature scale from 400° to 1100° with the nitrogen thermometer, and of extending it, if it should prove practicable to do so, to 1600° C., covering the region in which are found most of the mineral relations which it is the chief purpose of the laboratory to study. Two preliminary publications have been made during the investigation. One, a brief summary of preliminary work up to 1100°, was given before the National Academy of Sciences and the American Physical Society in April 1907;* the second covered the same ground at considerable length in 1908.† A final paper‡ extending the observations to 1550° and a supplementary paper§ on the use of thermo-elements throughout the entire range from zero to melting platinum appeared in 1910 and completed the work contemplated under the original plan.

The gas-thermometer problem at the present stage of its development has become primarily a problem for experimental study with two definite purposes, one to increase the accuracy of the measurements, the other to increase their range. The application of the gas laws is no longer subject to serious question. The progress of recent years has given us electric heating in place of gas and the consequent possibility of controlling the temperature with great certainty and exactness. It has also given us the metal bulb with a definite and measurable expansion coefficient and capable of holding the expanding gas without loss. It has discovered a gas which does not diffuse through the bulb or react with it chemically, which does not dissociate within the limits of practicable measurement, and of which the expansion can be expressed with reasonable certainty in terms of the Kelvin thermodynamic scale whenever it may prove necessary or desirable to do so. It has also discovered the source of the errors in the thermo-elements and a way to avoid them.

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* Abstract. Phys. Rev. 24, 531. 1907.

† Amer. Jour. Sci. (4), 26, 405–463. 1908.

‡ Amer. Jour. Sci. (4), 29, 93–161. 1910.

§ Amer. Jour. Sci. (4), 30, 1–15. 1910.

In 1904 Professor Holborn, of the Reichsanstalt, increased the range of this scale as far as 1600° C., the probable error of the new portion being 10°. Simultaneously with this effort, work was begun at the Geophysical Laboratory in Washington with a view to increasing the accuracy of the scale, first over the existing range (to 1150°), and later as much beyond this point as it should prove practicable to go.

The errors which have heretofore been present in measurements with the nitrogen thermometer have been reduced by the present investigation to about one-fourth their former magnitude, and the certainty of their evaluation is at least proportionately increased.

The following points have received particular attention:

(1) To provide a uniform temperature about the bulb by a suitable arrangement of electric-heating coils and diaphragms.

(2) To inclose the furnace in a gas-tight bomb in which the pressure outside the bulb can be maintained equal to that within for all temperatures. This offers three distinct advantages: (*a*) it provides against the deformation of the bulb through differences of pressure within and without in the region of highest temperatures, where the bulb material becomes softer; (*b*) by using the same gas within and without, there is no tendency for it to diffuse through the bulb wall; (*c*) it enables the initial pressure to be varied within considerable limits, thereby increasing both the scope and sensitiveness of the manometer. The sensitiveness in our instrument with this arrangement was about three times that of the Reichsanstalt.

(3) The expansion of the bulb material was determined with great care and is probably accurate within 0.5 per cent.

(4) The unheated space between the bulb and manometer has been reduced until the total correction in this hitherto uncertain region amounts to less than 4° at 1100°. An error of 5 per cent in the determination of its volume or temperature distribution is, therefore, practically negligible.

It is probable that these changes serve to reduce the uncertainty hitherto prevailing in the correction factors which require to be applied to the gas thermometer in the region of 1100° to less than one-tenth of its former magnitude. Furthermore, these improvements are equally applicable throughout the region above 1100° as far as the present measurements have extended (to 1550°).

The chief source of present uncertainty is the temperature distribution over the surface of the bulb in an air-bath. It would be possible to eliminate this error in the lower portion of the scale by substituting a liquid bath which could be stirred. In fact, this was done for temperatures below 500° in the earlier work of Holborn and Day, but has not so far been tried in the present investigation, because of the relatively secondary importance of the lower temperatures to the ultimate purpose of the investigation (the study of silicates). For the higher temperatures no satisfactory liquid bath has been found.

The interpretation of these measurements in terms of the melting-points of readily available substances encounters certain difficulties. The melting-point of pure salts is not sufficiently sharp and is somewhat difficult of interpretation. The metals which have commonly been used for the purpose, with the possible exception of nickel and cobalt, are, however, obtainable in sufficiently uniform purity to guarantee an accuracy within 1° at the higher temperatures.

No effort has been made to prepare metals of exceptional purity in our own laboratory, for the reason that such metals would not be available for general use and would therefore be of little service. We have accordingly adopted metals which are carried permanently in stock by dealers whose names are given in connection with each, from whom the same metal in a nominal quality equal to that which we used can be readily obtained. We have analyzed these with extreme care to show the exact content of the sample supplied us. We have duplicated the purchases ourselves, and have found no errors greater than 1° in their melting-point determination.

Another difficulty arises from the fact that the melting-points of the purest metals available for use as constants in reproducing a high-temperature scale (zinc, silver, gold, copper, and palladium) are distributed in such a way that, although they may be *located* upon the gas-thermometer scale with a probable error not greater than 0.5° at low temperatures or 1° at high temperatures, the calculation of a similar curve passing through these points may not suffice to *reproduce* the scale with this accuracy. In the region midway between zinc (418.2°) and silver (960.0°) the error of interpolation may amount to 2°, and between copper and palladium to 5°, even with metals of exceptional purity. Extrapolation is even more uncertain.

In order to facilitate as far as possible the application of these results in general practice, a typical thermo-element curve has been tabulated in small 10° intervals throughout its entire length from melting ice to melting platinum, together with a diagram showing the character and magnitude of the variation from this curve which may be expected to appear in other thermo-elements of the same nominal composition (90 parts platinum, 10 parts rhodium). With a new platin rhodium thermo-element of undoubted homogeneity, but unknown constants, it is quite practicable with this table to prepare a curve of its electromotive force for any temperature with sufficient accuracy for most purposes (say 5° at low temperatures and ± 10° above 1200°) from a single determination in melting copper. If this accuracy is inadequate, additional determinations of its electromotive force at other temperatures of the list below will help to fix it more closely.

There is no sure way to guard against the contaminating influence of metal-vapors upon a thermo-element in laboratory or industrial practice, although glazed porcelain is usually effective. There are very simple and rapid means of detecting contamination in an element and determining its distribution, and with a second element at hand for an occasional comparison there is little of serious danger from this cause. In any case, the slight inconvenience is well worth while wherever considerable accuracy is sought, for there is no other device yet available, in the region between 1100° and 1600°, which is comparable with the thermo-element in sensitiveness and general practicability.

In conclusion, the list of standard melting-points is given in tabular form, together with an estimate of the degree of trustworthiness to be accorded to each. Beside it for convenient comparison is the present Reichsanstalt scale. It may be added that no indication of a limit to the temperature attainable with the nitrogen thermometer or to its ultimate accuracy was discovered during the present investigation.

List of standard melting points.

Substance.	Point.	Atmosphere.	Crucible.	Temperature.	Reichsanstalt scale.
				°	°
Zinc	Melting and freezing.	Air	Graphite	418.2 ± 0.3	419.0
Antimony	Do	Carbon monoxide	Do	629.2 ± 0.5	630.6
Silver	Do	Do	Do	960.0 ± 0.7	961.5
Gold	Do	Do	Do	1062.4 ± 0.8	1064.0
Copper	Do	Do	Do	1082.6 ± 0.8	1084.1
Diopside (pure).	Melting	Air	Platinum	1391.3 ± 1.5	......
Nickel	Melting and freezing.	Hydrogen and nitrogen.	Magnesia and magnesium aluminate.	1452.3 ± 2.0	......
Cobalt	Do	Do	Magnesia	1489.8 ± 2.0	1575.1
Palladium	Do	Air	Pure magnesia	1549.2 ± 2.0	......
Anorthite	Melting	Do	Platiuum	1549.5 ± 2.0	......

In addition the following temperatures were incidentally obtained:

Substance.	Point.	Atmosphere.	Crucible.	Temperature.	Reichsanstalt scale.
				°	°
Cadmium	Melting and freezing.	Air	Graphite	320.0 ± 0.3	321.7
Aluminum	Freezing	Carbon monoxide	Do	658.0 ± 0.6	657
Li_2SiO_3	Melting	Air	Platinum	1201 ± 1	......
Platinum	Do	Do		1752[1] 1755[2] ± 5	....

(21) The methods of petrographic-microscopic research: Their relative accuracy and range of application. Fred. Eugene Wright. Publication No. 158, Carnegie Institution of Washington. (In press.)

During the past six years the work with artificial silicate preparations in the Geophysical Laboratory has imposed new and difficult problems to be solved by the microscope. Not only are such preparations very fine-grained, but the degree of accuracy of each measurement must be definitely known if it is to be applied without reserve to geophysical problems. To meet these new conditions, it has been necessary to devise new methods, involving extensive alterations in the microscope, and also to test the different methods available for the determination of the optical constants of minerals in the thin section and to ascertain their relative accuracy and general applicability. As a result of these tests, the methods best adapted for work with artificial and all fine-grained preparations are now fairly well established and their application has become in large measure a matter of routine.

Minerals are determined under the microscope by means of their crystallographic and optic properties; the more accurately such properties or constants can be ascertained for any given mineral, the more reliable and satisfactory is the determination. The optical properties thus made use of in the practical determination of minerals under the microscope are, briefly: refractive indices, birefringence, optic axial angle, optical character, extinction angle, color, and pleochroism. By means of these properties alone, it is not only possible to ascertain the crystal system to which a given mineral belongs, but also by a short process of elimination to determine definitely the mineral in question. This process has been carried to such refinement in certain instances, as, for example, in the isomorphous series of the plagioclase feldspars, that by optical properties alone the actual chemical composition of the particular plagioclase under observation can be obtained with considerable accuracy.

The optical and crystallographic characters which thus serve in the microscopical examination of minerals can be grouped into two classes, those of the first class (crystal habit, color, pleochroism and absorption, optical character of elongation, optical character of the mineral, and dispersion of the optic axes and bisectrices) being ascertained usually by direct observation without measurement, while for the second class (cleavage angles, extinction angles, optic axial angle, refractive indices, and birefringence) numerical values obtained by actual measurement are required. The properties included in the first group are used as a general rule only in an essentially qualitative way in microscopic work and can usually be recognized at a glance. For these the ordinary petrographic microscope suffices. But in the second group the quantitative element predominates; and, as such, demands accurate, precise measurements. In ordinary petrographic work, however, these properties are only very roughly measured, and are then expressed in general terms, as optic axial angle, large; birefringence, strong, etc., actual numerical data being rarely given. But with the increased knowledge of rocks and minerals thus attained, the demand for data which are precise and quantitative in character, rather than qualitative, has become more imperative, with the result that at the present time a thorough petrographic investigation should contain accurately determined optical constants of each of the rock-forming minerals examined, and, in critical instances, the probable error of each determination.

The present publication aims to offer a connected presentation of the entire investigation of the petrographic microscope so far as it has been carried, in which the different methods are coördinated and the significance and usefulness of each particular method is made to appear in its proper relation. An effort has been made to establish the limits of accuracy of each method as ordinarily used, and also the limits of accuracy theoretically attainable in measurements of this kind.

It may be stated, as a result of experience, that on clear individual grains measuring from 0.01 to 0.03 mm. in diameter, all the optic properties ordinarily employed in the petrographic microscopic investigation of minerals in the thin section can now be determined with a satisfactory degree of accuracy.

The introductory chapter contains a statement of the general theory of the microscope and the uses of its individual parts and accessories. Chapter I includes the application of the microscope in the determination of properties of the first class (color, pleochroism, absorption, crystal habit, optical, character, dispersion, etc.), which do not admit of numerical measurement. The properties of the second class which admit of accurate determination and numerical expression are treated in the following chapters: Chapter II, Refractive indices; III, Birefringence; IV, Extinction angles; V, Optic axial angles.

(22) Melting temperatures of sodium and lithium metasilicates. F. M. Jaeger. Jour. Wash. Acad. Sci., 1, 49. 1911.

Several carefully made and analyzed preparations of sodium and of lithium metasilicate were studied in this laboratory with a view to establishing a convenient standard melting temperature in the interval between the melting-point of copper (1082.6°) and that of diopside (1391°).

The melting-point of lithium metasilicate was found to be 1201° ± 1°, the uncertainty depending upon the care with which this synthetic preparation is made up. Sodium metasilicate is more viscous and undercools in solidifying to such an extent that no fixed solidifying temperature can be determined by the usual method of cooling curves. This fact explains the wide variations between existing determinations by different observers. The melting temperature is not subject to this limitation, and appears with reasonable promptness at 1088° with a probable uncertainty of 2°. The densities and some of the optical constants of the crystals were determined for the preparations used.

(23) Minerals and rocks of the composition $MgSiO_3$–$CaSiO_3$–$FeSiO_3$. Robert B. Sosman. Jour. Wash. Acad. Sci., 1, 54. 1911.

This paper is a partial report on a study from the statistical standpoint of certain rocks and minerals having a composition corresponding to a mixture of the metasilicates of magnesia, lime, and ferrous iron. The method of treatment is already familiar to mineralogists and petrologists through the publications of Vogt.

(24) The mineral sulphides of iron. E. T. Allen, J. L. Crenshaw, and John Johnston; with Crystallographic study by E. S. Larsen. (In press.)

The formation of iron disulphide was accomplished (1) by the action of hydrogen sulphide on ferric salts, or the action of sulphur and hydrogen sulphide on ferrous salts; (2) by the addition of sulphur from solution to amorphous ferrous sulphide or pyrrhotite; (3) by the action of soluble polysulphides on ferrous salts; (4) by the action of soluble thiosulphates on ferrous salts according to the equation $4M_2S_2O_3 + Fex_2 = 3M_2SO_4 + FeS_2 + 2Mx + 3S$. The first three methods may be generalized as *the action of sulphur on ferrous sulphide:* (1) in acid solutions; (2) in nearly neutral solutions; and (3) in alkaline solutions, since in (1) we may assume that ferrous sulphide first forms by the action of hydrogen sulphide on the ferrous salt, and in (3) we know that polysulphides first precipitate a mixture of ferrous sulphide and sulphur. Marcasite was obtained with certainty only by method (1); low temperatures and free acid favor its formation. A solution containing about 1 per cent of free sulphuric acid at 100° gives pure marcasite. Less acid solutions at higher temperatures give mixtures of marcasite and pyrite. The other methods give pyrite, which, under certain conditions, may be mixed with amorphous disulphide. It is possible that some marcasite may be formed by method (4).

Marcasite and pyrite were identified in the above products: (1) by microscopic examination and crystallographic measurement; marcasite crystals with the proper axial ratio were prepared for the first time; (2) by Stokes's oxidation method. This method serves also for the analysis of mixtures of the two minerals.

Marcasite changes to pyrite with evolution of heat. The change proceeds very slowly at 450° and is not accelerated by pressures even of 10,000 atmospheres. Marcasite is monotropic toward pyrite. This is in accord with the greater inclination of marcasite to oxidize, its assumed greater solubility, and the fact that its formation is conditioned by the composition of the solution from which it crystallizes.

The fact that marcasite never occurs as a primary constituent of magmas, while pyrite sometimes does, is explained by the fact that marcasite can not exist above 450°. The formation of pyrite in deep veins and hot springs is explained by the fact that the waters from which it came contained no strong acid. The marcasite of surface veins was probably formed from cold acid solutions, while mixtures of marcasite with pyrite were probably conditioned by higher temperature (up to 300° or 400°), or the presence of less acid, or both. Micro-organisms may have been active in the formation of pyrite and marcasite by giving rise to hydrogen sulphide.

Pyrrhotite was formed by the decomposition of pyrite or by heating marcasite, or by heating iron with excess of sulphur. The dissociation of pyrite into pyrrhotite and sulphur is readily reversible. At 565° (about) pyrite and pyrrhotite are in equilibrium with the partial pressure of sulphur in H_2S, which here amounts to about 5 mm. (data of Preunner and Schupp); at 550° in hydrogen sulphide, the pyrrhotite passes into pyrite, and at 575° the reverse action proceeds. At about 665° the evolution of sulphur from pyrite becomes rapid and a marked absorption of heat results. The pressure of the sulphur-vapor here reaches one atmosphere.

Pyrrhotite is of variable composition. Its composition at any temperature depends on the pressure of sulphur-vapor in which it is heated. Though it has not been found feasible to vary the temperature and pressure independently, a series of products were prepared by first decomposing pyrite and then reheating the resulting material to various measured temperatures in hydrogen sulphide and then chilling in the same or cooling in nitrogen. The products lowest in sulphur were obtained in the latter way. These products all resemble natural pyrrhotite in physical and chemical properties. Their specific volumes vary continuously with composition and pyrrhotite is therefore to be regarded as a solid solution of sulphur in ferrous sulphide. The maximum percentage of dissolved sulphur in synthetic pyrrhotite was 6.04 per cent at 600°. By extrapolation the saturated solution at 565°, below which point pyrite forms, was estimated to be 6.5 per cent. This corresponds closely to the maximum percentage of sulphur reported in natural pyrrhotite.

Equilibria between pyrrhotite and the partial pressure of sulphur in dissociated hydrogen sulphide were determined at different temperatures, by sufficiently long heating and then rapid cooling. The dissolved sulphur varied under these conditions from 6.0 per cent at 600° to 2.0 per cent at 1300°. The curve shows a discontinuity at the melting temperature, at the beginning of which there is a sudden decrease in the percentage of sulphur.

The melting-point of pure ferrous sulphide could not be exactly determined, because the compound dissociates at high temperatures into its elements. By heating it in a vacuum this dissociation was placed beyond doubt, though the dissociation was so slow that the melting-point could be located approximately. It may safely be put at 1170° ± 5°. In hydrogen sulphide, the melting temperature is raised because the solid solution thus formed contains more sulphur than the first portion of liquid to which it melts. The limits of the melting interval can not be determined as yet, but the maximum heat absorption falls at 1183°. In one atmosphere of sulphur-vapor this temperature rises to 1187°.

Crystals of pyrrhotite, the measurements of which are recorded under the crystallographic study, were repeatedly formed at various temperatures between 80° and 225° by the action of hydrogen sulphide on slightly acid solutions of ferrous salt containing some ferric salt. The product usually contained some crystals of disulphide.

Troilite is only the end-member of the pyrrhotite series and not a distinct mineral species. Thus far it has not been prepared free from metallic iron.

(25) Studies in ore deposition, with special reference to the sulphides of iron. E. T. Allen. Mining and Scientific Press, 103, 413. 1911.

A briefer presentation of No. 24 for the use of engineers.

(26) Quartz and fluorite as standards of density and refractive index. H. E. Merwin. Am. J. Sci. (4), 31, 429. 1911.

For checking the accuracy and adjustment of instruments, easily available standards are desirable. Standards of density correct to ± 0.001 and of refractive index correct to ± 0.0001 are particularly useful to mineralogists. Quartz and fluorite in clear colorless varieties appear to be the only minerals of wide distribution that are uniform enough in composition to serve as standards of this accuracy. Therefore the density and refractive index of these minerals at 20° have been investigated. The determined density of quartz from 12 localities is 2.6495 ± 0.001; of fluorite from 9 localities, 3.180 ± 0.001. By these standards the Westphal balance may be tested. The refractive index, ω_{Na}, of 5 quartzes, determined by means of the spectrometer and a standardized total refractometer, was found to be 1.54425 ± 0.0001; of fluorite, the value found was 1.43385 ± 0.0001. These values agree sufficiently closely with those of other observers.

(27) A method for determining the density of certain solids by means of Rohrbach's solution having a standard refractive index. H. E. Merwin. Am. J. Sci. (4) 31, 425. 1911.

By means of Rohrbach's solution, so prepared that the relation of its density to its refractive index is known, the density of suitable solids between 2 and 3.5 can be determined rapidly and accurately on the total refractometer by finding the refractive index of the solution while fragments of the solid are suspended in it. The solution saturated with mercuric iodide at 20° and at the density of ordinary orthorhombic sulphur (2.07) has, for concentrations between 2.25 and 3.4, the relation $d = 5.39n - 6.0865$, where d is the density and n the refractive index.

(28) A micrometer ocular with coördinate scale. Fred. Eugene Wright. J. Wash. Acad. Sci., 1, 60. 1911.

This new eye-piece consists essentially of a hollow brass cylinder which fits into the microscope tube as an ordinary eye-piece, and serves as support for a positive Ramsden ocular in the focal plane of which a finely divided 0.1 mm. coördinate scale is placed. The ocular has been designed to serve three purposes: (1) that of an ordinary micrometer eye-piece; (2) that of a coördinate ocular for the geometrical analysis of rock thin sections, either by the Rosiwal method or by the less accurate method of percentage areas; and (3) for the measurement of the optic axial angle of mineral plates in the thin section, provided that at least one optic axis appears in the field of view.

(29) Neuere Verbesserungen am petrographischen Mikroskop. Fred. Eugene Wright. Centr. Min., 555. 1911.

A brief discussion of the principles underlying the design, construction, and adjustment of the petrographic microscope, together with a description of recent improvements which have been made for the purpose of facilitating the accurate measurement of the optical properties of fine-grained mineral preparations, especially of artificial silicate melts.

(30) Recent progress in Calorimetry. Walter P. White.
I. The real *vs.* the supposed errors. Met. Chem. Eng., IX, 202. 1911.
II. Details of apparatus and method. Met. Chem. Eng. IX, 296. 1911.
III. Temperature measurement and corrections. Met. Chem. Eng., IX, 449. 1911.

A brief review of recent progress in calorimetry for the use of engineers.

DEPARTMENT OF HISTORICAL RESEARCH.*

J. Franklin Jameson, Director.

The following report, the sixth annual report of the present Director, covers the period from November 1, 1910, to October 31, 1911. The regular staff of the Department has been increased by the addition of Mr. Leo. F. Stock as a permanent member, and by the appointment of Miss Elizabeth P. Donnan, heretofore professor of history and dean in Rollins College, Florida, to take the place made vacant by the resignation of Miss Georgia Sanderlin, who after five years of most useful and devoted service, has withdrawn on account of illness. Mr. Leland and Miss Davenport have been in Europe throughout the year.

The quarters of the Department have remained unchanged. It has occupied the same rooms in the Bond Building, convenient and relatively satisfactory, but not so advantageous for our work as a separate building nearer to the Library of Congress would be. As the year closes, the erection of a tall building with blank walls, six feet from the windows of the Director's office, is beginning to make that and one of the other rooms impossible for want of light. From the middle of June until the middle of September the office work of the Department was in the main carried on elsewhere than in Washington, part of the staff working with the Director at North Edgecomb, Maine, part of it in Cambridge, and part of it in Washington.

For statements respecting the general plans of the Department and the purposes which its operations are intended to subserve, the Director begs leave to refer to former reports, and confines the present report to statements respecting the progress of specific publications and other undertakings. The publications of the Department, as has been explained in previous reports, fall naturally into two classes, the one that of reports, aids, and guides; the other that of textual publications of documents. Under these two heads, and a third relating to the miscellaneous activities of the Department, the work of the past year and the plans for 1912 will be successively considered in this report.

WORK OF THE PAST YEAR.

REPORTS, AIDS, AND GUIDES.

Three volumes falling within this division of the Department's work have been published during the year. Prof. Carl R. Fish's "Guide to the materials for American history in Roman and other Italian archives" came from the press in March, a volume of 289 pages, the contents and uses of which were sufficiently described in the last annual report. Historical reviews and European scholars familiar with the Vatican and other Roman archives have spoken of it since its publication in such a manner as to leave no doubt that it will fulfill the purposes for which it was intended—to call increased attention to the value of the Roman archives for important aspects of American history and to furnish investigators with guidance to the materials there preserved. Mention may be made of the most accessible of these testimonies, the notice of the book in the American Historical Review (XVI, 822), by Rev. Thomas Hughes, S. J.

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* Address, 500 Bond Building, Washington, D. C. Grant No. 678. $23,500 for investigations and maintenance during 1911. (For previous reports see Year Books Nos. 3–9.)

Prof. William H. Allison's "Inventory of unpublished material for American religious history in Protestant Church archives and other repositories," a volume of 254 pages, was issued in May. Its contents were described in the last annual report. From the nature of the case, a survey of several score of depositories which hitherto have been little used for purposes of historical composition and in many cases have never received systematic arrangement, must be regarded as a pioneer attempt. Deficiencies will from time to time be noted, and materials in repositories not known of at the time of composition of the volume will subsequently become known. But it is already evident that the book will be useful in stimulating work in American religious history along lines hitherto insufficiently followed.

In September appeared Mr. David W. Parker's "Calendar of papers in Washington archives relating to the Territories of the United States (to 1873)," a volume of 476 pages. Its arrangement, as described in last year's report, is in the alphabetical order of former and present Territories, under each of which, in a chronological order, appear brief notes of the contents and place of deposit of letters and other documents, to the number of nearly 10,000 in all, which Mr. Parker has found in the various scattered archives of Washington and which relate to the constitutional, political, and general history of the Territories down to 1873. Published so recently, the book has not yet come to the notice of historical scholars in any extended degree; but it is believed that it will signalize to them an unexpected wealth of historical material, in its particular line, in the Washington archives.

The "Guide to the manuscript materials relating to American history in the German state archives," by Prof. Marion D. Learned, of the University of Pennsylvania, reached the office of the Department, in its final manuscript form, in January. Its final preparation for printing took a great deal of time. This was partly due to the absence of several members of the Department from Washington. Of the diminished force remaining there, only such as had an accurate and quite extensive knowledge of earlier and later German as well as of earlier and later American history could profitably work upon it, and these were abundantly occupied otherwise. That which remained to do to the manuscript was in part owing to the circumstances of its preparation, which involved rapid examination of more than 40 archives, in a period of time by no means ample. Galley-proofs of the book reached this Department in July and the earlier part of August, but the author could not read them at once and they have but just been returned to the printing office. The book, including the elaborate index which it will require, will apparently be a volume of about 350 pages. In spite of some unevenness of product in a preliminary survey attempting to cover so much ground, it will serve many uses—uses perhaps the more varied on account of the complexity of the political organization of Germany in the past. Students of the diplomatic relations between the United States on the one hand and Prussia, Saxony, and other German States on the other, will find here exact indications of a large amount of material, especially full and detailed in respect to the first forty years after the acquisition of American independence. Students of the Revolutionary War will find indications of material, far surpassing in quantity anything that has hitherto been known, respecting the German auxiliary troops employed by Great Britain during that struggle, and presenting their observations regarding its events—the evidence of eye-witnesses neither American nor British, and therefore having an especial value. Most of all, students of the great movement of German migration to the United States, the source of at least one-sixth of our total population, will in this volume find guidance to documents illustrating this movement, from every section of the territories included in the present German Empire. The order of arrangement in the volume presents, first, the seventeen Prussian state archives in alphabetical order, beginning with Berlin, then the various archives of Bavaria, then those of the other States of the present Empire, in an alphabetical order.

At the opening of the year the manuscript of Professor Bolton's "Guide to the materials for United States history in Mexican archives" had just been received. Admirably as it had been prepared, its final preparation for the press proceeded with disappointing slowness, for reasons similar to those which have been mentioned in the case of Mr. Learned's book. Now, however, the manuscript in its final shape has gone to press. It will make a volume of about 400 pages of print. As little attention has in general been given by American historical scholars to the Mexican archives, it can be predicted with confidence that they will be surprised at the richness and variety of their contents illustrative of the history of the United States. Mr. Bolton's researches covered, first, the great central depository, known as the Archivo General y Público, in the City of Mexico; secondly, the archives of the executive departments and the other archives of the Federal city; and thirdly, various archives, civil and ecclesiastical, of those provincial capitals in the northern part of the Republic upon which portions of the present United States formerly depended in a political or ecclesiastical sense. In each of these three sorts of archives great stores of material for the history of Texas, California, New Mexico, Arizona, and the Southwest in general were found and listed. The narratives of explorers and missionaries may be instanced as the most interesting portion of the earlier material; the papers relating to boundaries and in general to diplomatic relations as the most important for the period after the securing of independence by the United States and Mexico; while the Mexican War and the subsequent developments of mutual relations between the two Republics are represented by what may literally be called enormous masses of fresh material deserving of the historian's attention.

Of the projected books respecting American papers in London archives, one, a "Guide to the manuscript material for the history of the United States to 1783, in the British Museum, in minor London archives, and in the Libraries of Oxford and Cambridge," by Prof. Charles M. Andrews and Miss Frances G. Davenport, was issued in 1908. Ideally this book should have been preceded by one on the materials in the Public Record Office, or chief London archive, for the same period, and followed by one on the materials in the various London archives relating to the period of United States history subsequent to 1783. The obstacles which have stood in the way of this order of issue have been described in previous annual reports. In the former case, that of the elaborate survey of Public Record Office materials for the colonial and revolutionary periods, which has for several years been in the charge of Prof. Charles M. Andrews, the main difficulty arose from the extensive reclassification of certain sections of the Public Record Office involved in the book. Of these, the sections embraced in the first half of the book are now in their final order of arrangement and Professor Andrews has during the past summer completed the work of recasting this half into a permanent shape, corresponding to the present classification. As it is now intended that his book shall appear in two volumes, the first embracing his general introduction upon the Public Record Office and his survey of the American materials in what are technically called the State Papers (State Papers, Foreign; State Papers, Domestic; Home Office Papers; State Papers, Colonial, etc.), the second presenting his description of what are technically called Departmental records (Admiralty, Audit Office, Custom House, Treasury, War Office, etc.) and the miscellaneous section embracing the papers of the High Court of Admiralty and various expired commissions and special collections, the stage of progress now reached may be defined by saying that volume I is now completed and substantially ready for the press. Volume II must await the completion of the process of reclassification. The long delays due to that process are regrettable, but have doubtless borne fruit in further perfecting of the material, which, as no American student of the present time or of any past period has ever acquired so large a knowledge of the Public Record Office as Professor Andrews, must, it is thought, prove invaluable to historical investigators.

The further completing of the Department's inventory of American materials in London archives consists of a guide to such of those materials as relate to the period since 1783. This would logically follow after the two volumes due to the labors of Professor Andrews and the volume supplementary to them, already published, prepared by him and by Miss Davenport. Since, however, the work of preparing this volume could be taken up at once, without impediment from official changes of classification, Dr. Charles O. Paullin and Prof. Frederic L. Paxson went to London in June 1910 upon a mission the history of which was partly related in the last annual report. Toward the close of the period included in that report the manuscript of Professor Paxson's section of the book, embracing the Foreign Office, Privy Council Office, and Board of Trade papers, from 1783 to 1837, arrived at the office of the Department, his labors having necessarily ended in September 1910. Dr. Paullin, to whom the Admiralty, War Office, and Colonial Office papers had been assigned (manuscripts in the British Museum having been dealt with jointly), continued in London until January 1911. His manuscript was received in March. Both sections of the proposed volume are now ready for press. Meanwhile, however, an opportunity of extending them has arisen in such a manner as to make necessary a considerable delay in publication.

In February 1910 application was made to the British Government, through the kind offices of the American Secretary of State and of the American Ambassador in London, for such official permissions as would allow Dr. Paullin and Professor Paxson to extend the scope of their researches beyond the year 1837. The departmental papers in the Public Record Office, it may be explained, are freely open to public examination down to 1837 (to 1850 in the case of War Office papers), though by special permission several American students have had the opportunity to proceed as far as 1848 in the Foreign Office papers. The effort to secure the permission in the general form required by the Department's purposes was kindly supported by Mr. Reid, American Ambassador, Mr. Bryce, British Ambassador in Washington, and others. In November consent to carry the examination of the Colonial Office papers down from 1837 to 1860 was accorded, and Dr. Paullin remained in London long enough to complete this part of the work upon the same scale as the remainder. Shortly after his return permission was received to extend the work, under proper official restrictions, to the same advanced date in the Foreign Office and Admiralty papers. Similar permission was presently received in the case of the Privy Council Office.

In view of these new openings, it seemed best to try to complete the work for the whole period from 1783 to 1860 before publishing the data already acquired. The Department was able at once to avail itself of the aid in London of Prof. Charles E. Fryer, of McGill University, a gentleman well versed in the English and American history of the period involved, who could for six weeks devote himself to the newly opened series, under instructions intended to secure uniformity of product with that of Dr. Paullin and Professor Paxson's labors. The mass of papers to be examined proved unexpectedly large;

Mr. Fryer, at the date in September when he was obliged to conclude, had covered only the Privy Council papers of the period involved and a portion, something like one-half, of the Foreign Office series. In October Mr. David W. Parker was sent to London to complete the work. The materials in the Public Record Office for the history of America since 1783 being exceedingly voluminous, the method followed throughout the whole of this book, both by Professor Paxson and Dr. Paullin and by Professor Fryer, has necessarily been that of presenting a somewhat full description of each volume without attempting to list or to calendar individual papers.

Just before the first of October 1910 Mr. David W. Parker began in Ottawa the making of a "Guide to the materials for United States history in Canadian archives." Of this piece of work, much the largest part consisted in examining and describing materials in the archives of the Dominion of Canada at Ottawa. This work was interrupted for nearly three months by an attack of typhoid fever, of which there was an epidemic in Ottawa at the time. Aside from this interruption in the spring, Mr. Parker's work went on steadily from October to September. The manuscript was then delivered to me. Mr. Parker having worked in the office of the Department in Washington for the better part of two years, and being familiar with its methods of dealing with manuscripts intended for print, his Ottawa report is practically ready for the printer at the present time. The remaining portion of the volume will consist of briefer reports upon the less copious, though in many cases important and interesting, materials for United States history preserved in provincial archives. Those of Quebec, especially the archives of the archbishopric, were examined in June by Prof. Frederick J. Zwierlein, of St. Bernard's Seminary, Rochester, New York, who was most kindly assisted in the work by the custodian of the ecclesiastical archives, Abbé Lionel St. George Lindsay. Father Zwierlein's report has been presented. The archives of the provinces of Nova Scotia and New Brunswick, at Halifax and Fredericton respectively, were examined by Mr. Parker in September, and his report upon them has been received. The archives of the province of Ontario can not at present be inspected with advantage, nor until they have been installed in new quarters made necessary by the burning about two years ago of that portion of the government buildings in Toronto in the vaults of which they were then stored. The archives of the other Canadian provinces contain relatively much less for the history of the United States. Measures have been taken to secure by correspondence brief reports upon them. Thus the report upon the Canadian archives is nearly finished; quite as nearly as circumstances permit.

Mr. Leland's mission in Paris will, by the date at which the present report is concluded, have been brought nearly to its conclusion. His work during the past year has, owing to the archive situation in Paris, been divided between the archives of the various ministries, the Archives Nationales, and the Bibliothèque Nationale. The latter case is like that of the British

Museum, or of any library into which manuscript materials come casually, requiring therefore listing or individual treatment. Of the archives of the executive departments, those of the Ministry of Colonies (largely transferred of late to the Archives Nationales) and of the Ministry of Foreign Affairs have been the chief objects of attention. In the latter archive, it may be well to mention, search was, of necessity, by no means confined to the series of volumes occupied with the diplomatic correspondence with the United States. While these formed the staple of the work, American affairs bulk so large in the series Angleterre, Espagne, Hollande, etc., at various periods, that a considerable examination of these is likewise necessary.

A merely preliminary report on the French archives would be without value. So much has been published upon the American, especially the Canadian, materials in French archives, though in no very systematic fashion, that all the information a preliminary report would be likely to contain could readily be extracted by the intending investigator from existing catalogues. Without expecting to describe every volume or carton containing American materials, Mr. Leland deems it essential, in order to prepare a work thoroughly worth while, to come as close as possible to indicating all such volumes, selecting for examination those volumes or cartons which seem especially likely to give results, and being careful to leave no misleading gaps. In the endeavor to give effect to this ideal he has been assisted by a small but competent clerical force, and has received especial advantage from the skillful and zealous aid of Mr. Abel Doysié.

In recent months it has been possible to accomplish something in a direction in which, under the conditions prevailing when Mr. Leland first went to France, it was not expected that any success could be obtained, namely, in the examination of missionary and other ecclesiastical archives in Paris. These will furnish useful additions to a volume which now abounds in valuable materials, often hitherto unknown, upon the history of the French colonies in America, and especially of Canada and Louisiana, the old Northwest and the old Southwest, upon the history of intercolonial wars and of the American Revolution, upon the diplomatic history of the United States, and upon that of its commercial and other relations with France during the period of independence.

In the last annual report of the Department the mission in Spain intended to be confided to Mr. Roscoe R. Hill was described as well as it was possible to describe it by way of prediction. Mr. Hill proceeded to Seville in January and has been occupied ever since, with a small amount of clerical assistance, in the heavy task of exploiting the materials for United States history in the section of the Archives of the Indies called "Papeles procedentes de la Isla de Cuba." The task has proved to be laborious to a degree much beyond expectation. The unordered condition of this section of the archives as described in last year's report made all quantitative estimates respecting the work precarious. Just before Mr. Hill sailed word was obtained from Mr.

Francis S. Philbrick, of New York, to whose knowledge of the Archives of the Indies the Department is indebted for many favors in this connection, of the fact that a list of the Papeles existed in the National Archives of Cuba. A copy was procured, no such list existing at Seville, but arrived after Mr. Hill's departure. It was clear in Washington from this list, and still more clear in Seville from Mr. Hill's first month of work, that, the *legajos* in this section being exceptionally large and the documents for United States history much more numerous than had been supposed, the making of what in strictness could be termed a calendar of them was out of the question. There are large portions of which an itemized list can be constructed with little difficulty from the tables of contents with which at an earlier time they were provided. But in general the method adopted, after such consultation between Mr. Hill and the Director as was possible, has been to prepare a description of each *legajo,* devised upon a uniform plan which will reveal to intending investigators as largely as possible all the points of contact with American history and with their particular studies which the papers in each *legajo* afford. These descriptions can probably be printed in a single volume of manageable size; the itemized lists can be held in manuscript for the present and placed at the service of investigators in various ways. The favors received by Mr. Hill from the American consul in Seville, Mr. Charles S. Winans, and from Señor Don Pedro Torres Lanzas, chief of the archive, deserve especial commemoration. It may be interesting to add that, upon the occasion of a visit of the King of Spain to the Archives of the Indies, Mr. Hill had the opportunity to explain to him the nature and bearings of the work upon which he was engaged.

TEXTUAL PUBLICATION OF DOCUMENTS.

The "Letters of Delegates to the Continental Congress relating to its Transactions" has remained in the charge of Dr. Burnett, who has devoted to it as much time as possible. The last remaining portion of the known material, a body of copies from the Laurens papers and other Revolutionary letters in the possession of the South Carolina Historical Society, at last arrived, in September. The work of arrangement, comparison, and elimination having been completed with the exception of this section, the editor's work during recent months has consisted mainly in the preparation of the annotations. These are confined within moderate limits, but are intended to make clear at every point both the origin of the fresh material respecting Congressional proceedings and the relation of it to the existing data presented by the formal Journals of the Continental Congress. At the time of the present report this work of editing has been carried through the year 1780 and a considerable part of it has been done for the years 1782 and 1783, the intermediate year having been for the time passed over, for practical reasons.

The process of revision to which Miss Davenport has been subjecting in London archives the portions of her book of treaties written in first draft in America does not readily permit numerical or quantitative statements of progress made. It may be said that the book, "Treaties, bearing on American history, concluded by European powers," is completed nearly to the time of the treaties of Westphalia.

The collection entitled "American proceedings and debates in Parliament, to 1783," will, as the title suggests, be derived from two sources, on the one hand from the official journals of the English House of Lords and House of Commons, of the Scottish Parliament, and of the Irish Lords and Commons, and on the other hand from the unofficial reports, printed and manuscript, of debates in these bodies. During the year Mr. Stock has brought to a conclusion the page-by-page search for American items in the 39 folio volumes of the Commons Journals, and has carried to 1676 the search in the Lords Journals. The extracts noted by him in the Commons Journals have been copied through half the volumes; or, more exactly, have been cut from the printed Journals possessed by the Department, and mounted to serve as printer's copy. This process is much cheaper and more satisfactory than copying. Our facilities for pursuing it have been greatly increased by the generous action of the American Antiquarian Society, which through its librarian, Mr. Clarence S. Brigham, presented to the Department last spring a series of duplicate volumes of the Commons Journals, which, with the volumes the Department already had, make up nearly a complete set. On the debates the only work done during the year has been to continue at the British Museum to 1770 (with part of 1774) the collation of the reports of debates in the Parliament of 1768–1774, taken down, partly in longhand and partly in shorthand, by Henry Cavendish, M. P. This process of collation has consisted in comparing the text of the earlier debates printed by Wright with the original manuscripts ostensibly used by him, and, since the divergences proved to be very wide, in preparing a proper copy of Cavendish's text. This work has been carried on in London by Miss Mary T. Martin.

MISCELLANEOUS OPERATIONS.

As heretofore, the editing of the American Historical Review has been carried on in the office of the Department and by its staff. In Paris Mr. Leland has continued to supervise the making of the calendar of papers in the French archives relating to the history of the Mississippi Valley, described in the annual report of two years ago, and undertaken by an associated group of historical organizations in the United States. This work has taken some of his time, but this has been compensated for by the manner in which its preparation has fitted in with, and in many particulars aided, the prosecution of his main task in the Parisian archives. For similar reasons he has been permitted to assist the Department of Archives and History of the State of Mississippi by making the necessary arrangements for extensive copying in the archives of Paris undertaken by that department, and by supervising its execution.

As in previous years, searches and copies have been made by the Department, or under its supervision, for organizations such as the Illinois State Historical Library, to whose service Mr. Stock was transferred for two months in the summer, and for many individuals. Letters of inquiry as to historical papers in Washington and other matters have been answered with the usual freedom. Their amount is at times burdensome, but it is felt that they should not be discouraged, partly because when one answers such a letter from a responsible person he is meeting a real need, and partly because such correspondence affords a means of keeping acquainted with the course of historical thought and work in the country at large. The Director has, as a matter of course, done what he could in small miscellaneous ways to further the interests in Washington of the American Historical Association and of American historical scholars. One such matter which may be instanced consisted in acting, by semi-official request, as an intermediary between the Royal Commission on the British Public Records, recently appointed, and the body of historical scholars in America making frequent use of the British archives; opinions and suggestions were collected somewhat systematically from these American scholars and presented to the Commission at the time when it was taking testimony of an analogous character. Professor Andrews, being in London during the sessions of the Commission, was invited to give evidence before it as the result of his long-continued searches on behalf of the Carnegie Institution of Washington.

A considerable part of the Director's time was given, in the spring of 1911, to endeavors to promote the erection in Washington of a suitable national archive building. A movement in that direction has been slowly progressing for more than thirty years, but the disposition of the present Congress seems to offer exceptional hopes of more rapid advance. The present state of things with respect to archives is so singularly bad, so strikingly inconvenient for historical workers—a hundred places of deposit, a hundred mutually independent custodians, many differing systems, insufficient care, storage in improper situations difficult of access and dangerous in respect to fire and damp—that while the Director is concerned with the matter primarily as chairman of a committee of the executive council of the American Historical Association on the subject, he can not fail to regard it as also an important part of his duty as director of a department of historical research, more important to the future of historical work in America than many parts of his regular duties, to do all that he can to promote the erection of a proper national archive building, and ultimately the creation of a better system. If the archives of the Government in Washington could be housed, arranged, and managed as similar national collections are housed and administered in European capitals, a long step forward would have been taken in the promotion of American historical work. During the past (extra) session of

Congress the Director, by invitation, appeared in this interest before the Committee on Public Buildings and Grounds of the House of Representatives, and, at the request of the chairman of that committee and of a member of the corresponding committee of the Senate, prepared bills which it is hoped may form the basis of enactments and appropriations in the next ensuing session of Congress. He has also, at the request of members of these committees, made active efforts, for which his position has given him exceptional advantages, to collect information, applicable to our circumstances, respecting the most approved archive buildings in European capitals.

PLANS FOR 1912.

The immediate future work of the Department is not likely to differ essentially in character from that of the past six years, though many improvements in process and method may be hoped for. Modifications of the departmental program may perhaps be looked for in two directions. On the one hand, when all the European archives most important for American history have been reported upon with sufficient fullness, the amount of effort expended upon European materials may be lessened and an increased amount bestowed on materials in America. Yet, on the other hand, the activity of our American historical societies and State historical departments with regard to these latter sorts of material is all the while increasing, and the efforts which have been made to persuade Congress to institute a working commission on national historical publications may at any time take effect. In that case, a number of domestic tasks which the Department has held in mind would be felt to lie properly within the field of such a national commission. The continuance of work upon the materials for American history in foreign archives might in that case be thought, by such a commission, an appropriate matter to be left in the hands of this Department. Political considerations would also make it less likely that certain American fields of work, such as documentary publications on the history of political parties, or on the history of slavery and the American negro, would be entered by such a national commission than that they should be left to the freer action of a private institution. None of these considerations, however, affect the plans made by the Department for the year 1911–1912.

REPORTS, AIDS, AND GUIDES.

It should be possible before the end of October 1912 to publish Professor Learned's "Guide to the manuscript materials relating to American history in the German State archives" and the first volume of Professor Andrews's "Guide to the manuscript materials for the history of the United States to 1783, in the Public Record Office." Professor Andrews expects to devote the summer of 1912 to the recasting and final revision in London of his second volume. It is by no means certain that the official reclassification of all the materials involved in the latter will have been completed by next summer, but it is believed that that process will have come near enough to its end to enable the manuscript of the volume to be given its final shape.

Dr. Paullin's and Professor Paxson's "Guide to the materials in British archives for United States history since 1783" must wait for the completion of their inventory of Foreign Office and Admiralty material, by addition of the tract extending from 1837 to 1860. It is expected that Mr. Parker, having gone to London in October for this purpose, will have been able by January to bring the work to a finish. It is hardly expected that the book can be published within the year, but composition upon it can be begun and perhaps finished.

The Canadian "Guide" must wait until at least February before it will be possible to obtain convenient access to the materials for United States history in the provincial archives of Ontario, and to prepare and add the section describing them. In the meantime, without sending special missions to places so remote as Winnipeg, Edmonton, Regina, and Victoria, it should be possible by correspondence with local authorities to obtain adequate data concerning such materials for the history of the United States as may be contained in the archives of the provinces of Manitoba, Alberta, Saskatchewan, and British Columbia. The whole book should be ready for print before next summer.

Mr. Leland returns to Washington in November, after a year and a half of heavy labor in Paris. While a part of his time will necessarily be devoted to other things, such as to his duties as secretary of the American Historical Association, he will expect to devote most of his time to the preparation for publication of his "Guide to the materials for American history in the archives of Paris." It is hoped that this may be completed without his going to Paris again. He is endeavoring, in the concluding weeks of the year just reported upon, to give such shape to all remaining portions of the search that it can be carried to its termination, after his departure, by his clerical assistants, under the skillful oversight of Mr. Doysié.

Given the amount, as now known, of the materials for American history in the "Papeles procedentes de la Isla de Cuba," it can be readily predicted that Mr. Hill's work in Seville must continue on its present lines throughout the year.

Of new work to be undertaken by the Department during the year, by far the most important will be the preparations toward an atlas of the historical geography of the United States. As much as possible of the time of the regular staff, and it is hoped the time of various research associates coming to Washington in various parts of the year, will be devoted to this work. There is a real and immediate need of such an atlas, but its preparation ought not to be hurried. There must be much consultation and deliberation as to inclusions and exclusions. Much research will be necessary among old maps which it may be thought desirable to reproduce. Many matters in American historical geography, even in the field of political boundaries and divisions, are disputed or still obscure. The geography of political, social, and economic movements—*e. g.*, of agricultural and industrial progress and of their relation to political history—is almost a virgin field. Explanatory letter-press should be used more largely than has been customary in such works, and must be prepared with as much care as any other product of historical scholarship. Technical questions concerning the execution of the maps must be considered with great care and with the best advice procurable. Altogether, it would not be reasonable to look forward to doing more in 1912 than to define the bounds and details of the enterprise in as many respects as possible, to submit the table of contents in some manner to criticism by those entitled to judge or suggest, to fix upon the program of procedure, and to prepare some of the maps and certain sections of the letter-press.

TEXTS.

If Dr. Burnett is able to spend as large a part of his time in 1912 upon the "Letters of Delegates to the Continental Congress" as in 1911, it seems not unlikely that he may be able to complete the work.

Miss Davenport will have all her time free for the book of treaties, and will bring it a year nearer to completion. The documents themselves, at all events, as distinguished from the introductions and annotations, will be given their final form, a photographic or manuscript copy being obtained of whatever is in each case the authoritative text.

The extracts required for the volumes of "American proceedings and debates in Parliament," from the Lords and Commons Journals, the Irish parliamentary journals, and the Acts of the Parliament of Scotland, will probably be completed within the year. Some progress will also be made with respect to the debates, especially with respect to those still remaining in manuscript, in the British Museum and elsewhere in England.

MISCELLANEOUS OPERATIONS.

The Department will no doubt maintain in 1912 activities similar in general to those described above, under this head, in the report relative to the last twelve months.

DEPARTMENT OF MARINE BIOLOGY.*

ALFRED G. MAYER, DIRECTOR.

During the year our whole scientific outlook has been broadened through improvements in the equipment of the laboratory. Most important in this respect has been the building of the new yacht *Anton Dohrn,* named in honor of the memory of the founder and director of that greatest of all marine laboratories, the Stazione Zoologica of Naples. Anton Dohrn's life was a record of self-sacrificing devotion to altruistic ideals, which his high ability as an executive enabled him to place in practice to the lasting benefit of science. Yet, high as his purpose was and successful as his achievements were, we of America whom he honored by his friendship esteem him even more for the rare traits of character that distinguished his every thought and act, for his was an all-embracing culture, and his love of art, poetry, literature, and of the incomparable beauty of the Neapolitan region, rich in its historic associations, served but as a setting for his keen, incisive interest in biology. Above all, he was a German gentleman of the highest type—a follower of truth wherever truth might lead him, he showed to all men, from prince to peasant, equal consideration and sympathy.

The *Anton Dohrn* was constructed by the Miami Yacht and Machine Company at a cost of $25,000, and is the largest yacht which has as yet been built in southern Florida. Madeira, a hard, mahogany-like wood found upon the Florida Keys, and the best yellow pine were used in the construction, it having been found that these woods resist the attacks of dry-rot even when subjected to the damp, hot climate of the tropics. To resist the electrolytic action so powerful in the warm waters of the Gulf Stream region, all fastenings beneath the water-line are of brass or tobin bronze. The yacht is 70 feet over all, 66 feet upon the water-line, with 16 feet beam, and a draft of 5 feet. There are two water-tight bulkheads, one forward and the other abaft of the engine-room, which occupies the amidship section of the vessel. The vessel has two bronze propellers and two Eddystone Globe engines of 50 horsepower each. The engines are wholly independent one of the other, each having its own gasolene tanks, pumps, batteries, etc., so that an accident affecting one can not impair the efficiency of the other. These engines and all other machinery of the yacht were installed by our chief engineer, Mr. John Mills, and it should be said to his credit that from the day of their trial trip they have run without mishap and with constantly increasing efficiency. Our own crew worked upon the construction of the *Anton Dohrn,* the sailing-master, Captain Lundblom, being president of the Miami Yacht and Machine

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*Situated at Tortugas, Florida. Grant No. 679. $16,480 for investigations and maintenance during 1911. (For previous reports see Year Books Nos. 3–9.)

The "Anton Dohrn" at Tortugas, Florida, July 4, 1911.

The "Anton Dohrn," July 1911.

Company, and I have pleasure in expressing my full appreciation of the thorough excellence of their work.

The *Anton Dohrn,* when upon long courses, makes an average speed of 10 knots, but is more economically run at 8 knots. Thus her limiting radius at a speed of 10 knots is 875 miles, or 87½ hours; whereas at 8 knots her radius is 1,350 miles, or 169 hours. Her license was granted at Key West, Florida, on May 31, 1911, her number being 208,685, signal letters LBVW, 30 net and 45 gross tons, temporary certificate of enrollment No. 15, Alfred G. Mayer, master.

On October 17, 1910, a great hurricane passed over the Tortugas. The storm commenced at 8 o'clock in the morning, the wind being from the east, and it constantly increased in violence until the center passed over the island at about 2^h 15^m p. m., by which time the wind had veered to the north. The central calm lasted about 15 minutes, after which the hurricane set in very suddenly from the southwest, to die down by nightfall. The aneroid barometer at the lighthouse sank to 27.96, and the wind is believed to have attained a velocity of about 100 miles per hour. The glass sides of the lighthouse were shattered, fragments of seaweed (*Sargassum*) were lodged upon the lamp, 160 feet above the sea, and the sand ridges thrown up along the beaches are higher than those of any previous storm, not excepting the well-remembered ones of 1846 and 1876.

Of the laboratory buildings, the sailors' dormitory was wholly destroyed and a portion of the roof of the main building was blown 500 feet to the southward. The kitchen and aquarium, which are upon the water's edge, sank 3 feet through the washing away of their foundations, but were otherwise not seriously injured. The machine-shop, which is 40 feet long and 20 feet wide, was blown from its foundation and moved 5 feet to the southward; but, being very strongly constructed, by Mr. Mills and our own men, it suffered no material injury. Our windmills were overturned and nearly every plant in our garden was destroyed, including all of the *Solanum* being cultivated for Professor Tower's experiments. In fact, every leaf of every plant was torn to shreds by the onrush of sand-filled air and salt spray, which drove over the entire island.

In viewing the destruction one notable feature was at once apparent: those structures which had been built by our own men were intact, while the portable buildings imported from the north were seriously damaged. The Institution having generously appropriated $4,000 to repair and strengthen the buildings, we have employed our own men upon this task and they have accomplished it in the best possible manner. An investigation of conditions in Key West showed that wooden buildings, if properly constructed, are better able to withstand hurricane winds than are those of concrete, and with this in view we have replaced all structures in wood so strongly braced that we now feel confident the buildings will withstand a storm such as that of the late hurricane without suffering any material injury. The building which was destroyed has been replaced by one 87½ feet long and 34 feet wide, surrounded on the south, east, and west by a veranda 14 feet in width. It will be used as a laboratory building, especially for researches in physiology, while our engineers and sailors will be comfortably housed in a newly constructed wing designed to strengthen and enlarge the machine-shop.

These improvements enable us to accommodate 14 investigators at one and the same time instead of 8, as formerly. In fact, the acquisition of so excellent a sea-going vessel as the *Anton Dohrn* made it imperative that the laboratory itself should be improved to meet the requirements of this new era of enhanced efficiency and broader possibilities in oceanographic and other work initiated by the possession of our new vessel. We now purpose to conduct studies of the ocean currents of the region and to make voyages of biological purport to the rich coral reefs of the Bahamas, as well as to study the geology and zoology of Cuba, Haiti, and Jamaica, and from among the able young investigators of America and Europe we have already selected certain of those who hope to conduct researches upon these voyages. No geographical limits can be set upon research, and an expedition to the Great Barrier Reef region of Australia has become necessary in order to extend and render altogether conclusive the researches of Vaughan, Harvey, Cary, Drew, and Tennent which have been commenced at Tortugas. In fact, the study of the whole ocean and its life falls within the scope of the Department of Marine Biology, not merely the bird's-eye view of nature afforded by any single region. Especially is this true to-day, when biology has become closely allied to chemistry, medicine, and physics, and the necessity for seeking out certain few specific forms for experimental study has supplanted the general collecting and descriptive work of a past generation.

During the past year our sailors have been busily engaged in constructing the *Anton Dohrn* and in erecting the new buildings at Tortugas to replace the old ones destroyed or damaged by the hurricane of 1910. We have among our men some of the most highly skilled mechanics in southern Florida, and the necessity for granting them sufficient time in which to accomplish the important work of placing the laboratory upon a new footing has prevented our extending facilities for research to more than eight investigations during the year.

Mr. Mills and the sailors remained at Tortugas until October 1, engaged in the reconstruction of the buildings.

In September 1910 the Director went to Torbay, Newfoundland, and to Halifax, Nova Scotia, to study the Ctenophoræ of the northern waters. On behalf of the Department of Marine Biology he has pleasure in expressing his sense of gratitude to the Honorable Mr. A. W. Piccott, Minister of Marine and Fisheries of Newfoundland, for many courtesies and for substantial aid in providing a boat for these studies.

In February 1911 Prof. Ulric Dahlgren, of Princeton University, was sent to Hampton Roads, Virginia, to enable him to collect young stages of *Astero-*

scopus, the "star gazer," the eye muscles of which develop into electrical organs capable of giving a severe shock. Professor Dahlgren is making a study of the histology of these muscles in various stages of growth, and it is expected that his work will be pursued for several years before being ready for publication.

During April and May 1911, the Director, together with G. Harold Drew, Esq., B. A., of Christ's College, Cambridge, and E. E. Reinke, Esq., of Princeton University, went to Jamaica and established a temporary laboratory at Port Royal. While in Jamaica much kindness was shown us by the Honorable Mr. Johnstone, Acting Colonial Secretary of the colony, and by Dr. H. H. Scott, Director of the Hope Laboratory, and on behalf of the Department I have pleasure in expressing our gratitude to these gentlemen.

Finally, the yacht *Anton Dohrn* having been completed in a most thorough and satisfactory manner, we steamed out from Miami on June 3 and went at once to Tortugas, whither Messrs. Drew and Vaughan had preceded us. We remained at Tortugas until August 7, after which the Director went to Woods Hole and to Halifax, Nova Scotia, to continue physiological studies commenced this year at Tortugas. In this connection it is a pleasure to thank Prof. Frank R. Lillie, Director of the Marine Biological Laboratory at Woods Hole, for kindly placing the facilities of the laboratory at our disposal.

The following investigators have pursued researches under the auspices of the laboratory during the year:

Dr. L. R. Cary, of Princeton University; January 1911 and June 26 to August 7.
Prof. Ulric Dahlgren, of Princeton University; February 1910.
G. Harold Drew, Esq., B. A., Christ's College, Cambridge; April 20 to June 30.
Dr. E. Newton Harvey, Princeton University; June 26 to July 28.
Dr. Merkel H. Jacobs, University of Pennsylvania; July 1 to 28.
Prof. William H. Longley, collector and investigator, Goucher College; June 1 to July 28.
E. E. Reinke, Princeton University; April 20 to May 25.
Dr. T. Wayland Vaughan, U. S. Geological Survey; June 1 to 30.

In addition to the above, Dr. Stewart Paton came to Florida intending to study the relations between the earliest movements of the heart and the correlated condition in development of the nervous system in the embryo of the loggerhead turtle, *C. caretta.* Before reaching Key West, however, he was threatened with illness, which obliged him to forego his research at Tortugas. The material for the research was, however, collected for him by Dr. Longley, and it is hoped that he may be able to proceed with his studies.

Dr. Cary continued his studies upon the growth of gorgonians, and other problems which he discusses in his preliminary report published herewith.

G. Harold Drew, Esq., carried out observations which justify the belief that he has probably discovered one of the most interesting facts yet revealed through the study of oceanography. He finds that the most abundant bacillus at depths between 10 fathoms and the surface in the ocean off Jamaica and Tortugas is a form that possesses the capacity to convert all the nitrates of the water into nitrites and finally to expel the nitrogen from the sea in the form of gas, thus depriving the surface waters of the ocean of nitrogen. This relative scarcity of nitrogen in the tropical ocean accounts for the paucity of plant life in warm seas as compared with the conditions seen in temperate regions, where great masses of *Fucus,* etc., cover the rocks.

Dr. Drew also showed that the formation of ammonia and final liberation of nitrogen by this bacterium would leave the calcium free to combine with the dissolved CO_2 of the ocean, thus causing a precipitation of calcium carbonate. The vast areas of chalky mud of the Bahama-Florida region and in the coral regions of the tropical Pacific may have been formed in this manner. This denitrifying bacterium appears to grow best in a moderate light and to be most abundant at a depth of 10 fathoms, below which it gives place to another, non-denitrifying form, which appears to be characteristic of the deep sea and is readily killed upon exposure to sunlight.

His lucid report herewith presented demonstrates that these studies must be undertaken with the best possible equipment of apparatus in Arctic, Temperate, and Tropical oceans, and it is our hope that this most suggestive research may be continued under the auspices of the Department of Marine Biology.

Dr. E. Newton Harvey continued his studies of the efficiency of alkalies in penetrating living cells. He found that in KOH, NaOH, $Sr(OH)_2$ the muscles and nerves cease to function before the alkali can penetrate the cells, whereas in ammonia and the amines the cells are penetrated and lose color before the muscles and nerves cease to function. With the exception of trimethyl amine, the amines and inorganic hydroxides destroy nervous conduction *before* the muscles lose their power of contraction. He concludes that a surface change conditions contraction and conduction.

Dr. Harvey also studied the relation between penetration and cytolysis, and he made an interesting observation upon the subject of nerve fatigue, entrapping a contraction wave in a ring of tissue, through which it traveled 457 miles in 11 days.

Dr. Merkel H. Jacobs carried out a study of the physiological reactions and environmental relations of several species of protozoa which infest the sea-urchin *Diadema setosum* at Tortugas.

Prof. William H. Longley studied the œcology of the varied animal life inhabiting the gulf-weed, *Sargassum,* and it is to be hoped that he may continue this interesting subject.

Mr. E. E. Reinke investigated the development and morphological relationship of the two forms of spermatozoa found in certain prosobranch mollusks in Jamaica.

Dr. T. Wayland Vaughan met with encouraging success in his studies of the growth of reef corals, obtaining excellent photographs showing the annual growth of the many colonies he is now rearing under natural conditions. He also obtained bottom specimens from the quicksands between Rebecca

Light and the Marquesas. His studies of coral reefs and of the life history and struggle for existence among corals is the most intensive and most carefully controlled yet undertaken, and it will soon become necessary for him to extend his field of observation to include the Great Barrier Reef region of Australia in order that his results may become of world-wide significance. In April and May 1912 we expect that he may visit the Barrier Reef of Andros Island, Bahamas, the greatest coral reef of the Atlantic. The *Anton Dohrn,* supplemented by the *Sea Horse* and a launch, will constitute a suitable fleet for such an expedition.

Prof. W. L. Tower's experiments were terminated by the hurricane of October 1910, but with characteristic pertinacity he expects to replant his *Solanum* and begin anew. It is a rare privilege to the laboratory to lend its aid to him in this difficult investigation. Indeed, it may be said that the course of a worthy research "never ran smooth," yet it is through just such studies that discoveries are made.

A. G. Mayer conducted several researches—one upon the reactions to temperature of animals which extend from arctic or temperate regions to the tropics. He concludes that in order to survive in the shallow or surface waters of the tropics an animal must be able to withstand a temperature of at least 29° C., whereas to live in the arctic regions a marine animal must tolerate being frozen into the ice; thus the common Scyphomedusa *Aurellia aurita* ranges from pole to pole, and is found in all oceans, being especially abundant in cold seas. At Halifax, Nova Scotia, it pulsates between —1.4° and 29.7° C., being most active at about 20°, and it survives being frozen solidly into the ice. The same species of *Aurellia* at Tortugas, however, is active between 7.75° and 38.4° C., being most active at 28°, and being killed if frozen. Evidently the constitution of the medusa has changed greatly upon its becoming acclimated to the tropics. Similarly, *Pennaria* at Woods Hole, Massachusetts, survives freezing, whereas at Tortugas it is killed. The rule appears to be that when a cold-water species becomes acclimated to a tropical sea its optimum temperature, death temperature, and temperature of maximum activity are raised, while at the same time it loses the power to withstand cold. Thus apparently some change comes over the colloids which causes them to congeal at a higher temperature in the tropics.

A typical arctic genus of Scyphomedusæ is *Cyanea,* and *C. arctica* remains active until frozen into the ice, and is apparently uninjured by this treatment, for it recovers as soon as the ice melts sufficiently to permit it to pulsate. On the other hand, a temperature of 26.5° to 28° is fatal to it, and this accounts for the absence of this genus in tropical seas.

On the other hand, the rhizostomous medusa *Cassiopea frondosa* belongs to a strictly tropical genus. It remains active between 12.1° and 40°, and is killed if cooled to 8.3° C. Evidently it could not survive in temperate seas. The above are only a few of the forms already experimented upon, and the research will be widely extended and the attempt made to determine whether these reaction-changes can be brought about in one and the same individual, or whether generations must elapse before acclimatization is accomplished.

In another research the Director studied the starvation of *Cassiopea xamachana.* In general, the loss of weight during the day is proportional to the initial weight at the beginning of the day. Hence the weight of the starving medusa is represented by the formula $y=W(1-a)^x$, where y is the weight upon any given day, W the weight of the medusa when starving began, $W(1-a)$ the weight at the end of the first day of starving, a being a constant and x the number of days starving has continued. The medusæ, if starved in diffuse daylight, can survive 41 days and be reduced to 1/142 their original weight. They lose weight more rapidly, and do not survive as long in the dark as in light, and in the dark their parasitic algal cells become greatly reduced in number, although not entirely killed. Also, in the dark the medusa gives out much more CO_2 than in the light, and it is evident that the oxygen set free by the algal cells in daylight serves to sustain the medusa, while the CO_2 serves to maintain the plant cells.

Medusæ starved in the dark decline in weight in fair accord with the formula $y=W(1-a)^x$; but if starved in diffuse daylight their loss of weight for the first 20 days is slower, and the medusæ remain heavier than should be expected according to the above-mentioned formula. Thus it appears that the medusa effectually feeds upon its algal cells, which multiply and maintain an internal source of food for their host. In the dark, however, these algal cells do not reproduce, and are soon reduced to a practical zero, thus failing to sustain the medusa. This probably applies also to the stony corals and actinians as well as to rhizostomous Scyphomedusæ.

In another research the Director investigated the interactions between the cations sodium, magnesium, calcium, and potassium in producing movements in marine invertebrates. Calcium can not produce tetanus in the absence of sodium; hence the so-called "calcium tetanus" is probably produced by the chemical combination of calcium and sodium with a proteid. The stupefying effect of magnesium is cumulative, increasing with the increase of concentration of the magnesium ion; but this does not apply to calcium, for this produces almost its normal effect very suddenly upon attaining a certain concentration, and increasing the pressure of the Ca ion beyond this has relatively little effect.

Mechanical pressure upon the subumbrella of *Cassiopea* reduces its sensitiveness to stimuli; hence a contraction-wave produced by a stimulus travels from an unpressed, or recently pressed, to a pressed or long pressed place, whether this be from cathode to anode or from anode to cathode.

Medusæ which under normal conditions pulsate about 45 times per minute maintain a rate of 129 if made into a circuit-ring, and this ring is capable of responding to 152 induced shocks per minute by 152 pulsations for an indefinite time, or 252 shocks for about 2½ minutes. Thus the nerves are capable of transmitting and the muscles of responding by contraction to more than three times as many stimuli per minute as the sense-organs engender in nature, and for a short time they can maintain about 5.5 times the normal rate, although this soon causes fatigue and an inability to respond to so rapid a stimulation.

Twenty-one scientific papers embodying original work, and two discussions, were published during the year as results of investigations conducted at Tortugas. Thirteen of these original papers appeared in volumes 3 and 4 of Researches from the Tortugas Laboratory, Publications Nos. 132 and 133, published by the Carnegie Institution of Washington, the contributors being Hargitt, Hartmeyer, Harvey, Hooker, Linton, McClendon, Mayer, Pratt, Stockard, Stromsten, Tennent, Tennent and V. H. Keiller, and Vaughan.

Eight additional researches were published elsewhere as follows:

Westindische Seeigel und Seesterne (Tortugas echinoderms) L. Döderlein und R. Hartmeyer, in Zoologische Jahrbücher, 1910, suppl. 2, Heft 2, pp. 145–156.

The mechanism of membrane formation and other early changes in developing sea-urchins' eggs as bearing upon the problem of artificial parthenogenesis, by E. Newton Harvey, in The Journal of Experimental Zoology, vol. 8, No. 4, July 1910, pp. 355–376.

Studies on the permeability of cells, by E. Newton Harvey, in The Journal of Experimental Zoology, vol. 10, No. 4, May 1911, pp. 507–556, 3 figures.

Medusæ of the world, 3 volumes, 728 pp., 76 plates, 427 text-figures, quarto, by Alfred G. Mayer, Publication No. 109, Carnegie Institution of Washington.

Alexander Agassiz, by Alfred G. Mayer, in Popular Science Monthly, October 1910.

Alpheus Hyatt, by Alfred G. Mayer, *ibid.*, February 1911.

Polychætous annelids from the Dry Tortugas, Florida, by Aaron L. Treadwell, 1911. Bulletin of the American Museum of Natural History, vol. 30, pp. 1–12, 29 figures.

Further data on the homing sense of noddy and sooty terns, by John B. Watson, in Science, vol. 32, pp. 470–473, October 7, 1910.

In conclusion, I have pleasure in thanking Dr. E. K. Sprague, of the U. S. Marine Hospital at Key West, who kindly granted the facilities of the hospital to the steward of the *Anton Dohrn* during an illness, and I also wish to thank Capt. E. E. Hayden, U. S. Navy, commandant of the naval station at Key West, for much kindness.

On behalf of the Department of Marine Biology, it is a privilege and pleasure to acknowledge the gift of a beautifully designed silver table service to the *Anton Dohrn* from the Miami Yacht and Machine Company, presented by Messrs. Lundblom and Peck, of Miami, Florida.

Prof. Reinhard Dohrn, Director of the Naples Laboratory, presented a bronze bas-relief of his father, which occupies an honored place upon the wall of the cabin of the *Anton Dohrn*.

Although the year has not been unproductive of discoveries in science, it should be regarded chiefly as potential in its import, witnessing as it has the launching of the staunch sea-going yacht, the *Anton Dohrn*, and the enlargement of our laboratory facilities upon Loggerhead Key, Tortugas.

REPORTS OF INVESTIGATORS.

The Permeability of Living Cells for Alkalies, by E. Newton Harvey, Princeton University.

THE PERMEABILITY OF CELLS FOR ALKALIES.

The use of neutral red as an indicator within the cell affords so delicate a means of detecting the presence of the hydroxyl ion that I have continued my studies on the permeability of cells for alkalies, a research begun at Tortugas in 1910. My aim has been to determine the time relation between the color change of the indicator and the observed change in appearance or in functional activity of the cell produced by representative alkalies. The muscle-nerve tissue of *Cassiopea xamachana,* the muscles of *Salpa,* of the tentacles of *Pennaria* and marine annelids, the swimming-plates of the ctenophore *Beroë,* the ciliated cells of trochopores and larvæ, and the eggs of many marine animals may be employed to determine the above relation. Only a small amount of alkali can be added to sea-water without precipitating the magnesium, so that a Mg-free sea-water was used to dissolve the alkali. Mg-free sea-water is a fairly well-balanced medium for marine tissues.

Preliminary studies on the permeability relations of marine animals for ammonia, the amines, and inorganic hydroxides confirmed, in practically every detail, previous results obtained with plant cells and *Paramæcium.* The eggs of *Holothuria floridana, Hipponoë esculenta, Pomatostegus stellatus, Toxopneustes variegatus,* and *Eunice fucata,* the gonads and subumbrella epithelium of *Cassiopea xamachana,* the tentacles of *Sabella,* and the respiratory tree tissues of *Holothuria floridana,* if stained in neutral red, are all entered very rapidly (one-half minute to 5 minutes) by ammonia, methyl, dimethyl, trimethyl, ethyl, propyl, and isopropyl amines (N/250 to N/500), but not by tetraethyl ammonium hydroxide, NaOH, KOH, or $Sr(OH)_2$ ($>\frac{1}{2}$ hour). If the tissues are replaced in sea-water after decolorization in the amines or ammonia, the red color returns, providing the cells are not so small that the free neutral red base has had time to diffuse out. The color return is markedly more rapid in ammonia and trimethyl amine. These two substances are considerably weaker bases than the rest of the amines and they are correspondingly less toxic, as the following experiments indicate.

If unfertilized *Toxopneustes* eggs are placed in N/250 solutions of ammonia, the amines, and $N(C_2H_5)_4OH$ for two minutes, then returned to sea-water and fertilized, the eggs in all solutions begin to develop and segment, some irregularly, although the decolorization is instantaneous in all solutions (except $N(C_2H_5)_4OH$). If returned to sea-water after 5 minutes only unsegmented eggs and fragments are found in the dishes of eggs treated with methyl, dimethyl, ethyl, and propyl amines, a few irregular segmentations in isopropyl amine, but numerous segmentated eggs in ammonium hydrate, trimethyl amine, and $N(C_2H_5)_4OH$. Eggs left permanently in solutions of the latter three alkalies cytolyze much less readily than eggs left in solutions of the remaining amines. $N(C_2H_5)_4OH$ behaves in every respect like the inorganic hydroxides and may be taken as a representative of that class in the above experiment.

The same relations hold good for the epithelio-muscle tissue of the subumbrella surface of *Cassiopea xamachana.* The granules which stain are probably mucous globules, although a minute histological examination will be necessary to determine the exact relations of these granules to the individual epithelial, nerve, and muscle cells. They are situated in the outer third (away from the muscle fibrillæ) of the epithelio-muscle layer as viewed in a cross-section of the fresh tissue. When treated with chloroform-saturated sea-water, practically all of the stained granules are sloughed off in an abundant mucus. In this mucus the red granules are quickly changed to yellow in the inorganic alkalies, such as NaOH or KOH. If the living tissue is placed in N/250 NaOH, KOH, $Sr(OH)_2$, or $N(C_2H_5)_4OH$, the red granules remain red for a long time ($>\frac{1}{2}$ hour), and in fact only become yellow when they pass out in the mucus. Mucus formation is induced also by alkali or any treatment (dilute acid or heat) drastic enough to be eventually injurious. Nevertheless, the *muscles rapidly (2 to 10 minutes in N/250 solution) lose their power of contraction and the nerves their power of conduction before the color change occurs.*

In ammonia and the amines, on the other hand, the color change takes place in <2 minutes in N/250 solution and *only afterwards (2 to 15 minutes) do the muscles stop contracting and the nerves conducting.*

Contraction and then conduction cease much less rapidly in N/250 NH_4OH and trimethyl amine than in the rest of the amines, in which conduction generally ceases slightly *before* the muscles lose their power of contraction on direct stimulation. So long as the alkalies penetrate readily, the stronger (more highly dissociated) they are the more toxic they are. But the inorganic alkalies are much less toxic than should be predicated from their degree of dissociation. Observation shows that they penetrate all cells very slowly, and may produce marked functional changes (cessation of contraction and conduction) before affecting the neutral red indicator. Therefore their point of attack must be the surface of the cell. The above observations on *Cassiopea* are strong arguments in favor of the view that the essential conditioning change in contraction and conduction is a surface change.

It is noteworthy, also, that in the inorganic hydroxides, conduction ceases a considerable time before contraction, an exception to the general rule that most poisonous substances affect the muscles of *Cassiopea* before the nerves, although the nerve network is outermost (nearest the solution). Presumably the alkali can only diffuse into the tissue through the intercellular spaces, and so collects about the nerve network near the surface in sufficient concentration to affect the nerves before the muscles.

It is a general rule, which holds for many kinds of tissue, that NaOH (taking this as an example of the strong inorganic alkalies) only penetrates *after* the cells have been affected. Contraction of the muscle bands of *Salpa,* in which there is no question but that the red-stained granules are within the fibers, ceases before the red is turned to yellow. Movement of the gills and tentacles of *Amphitrite,* of the tentacles of *Pennaria,* of the ciliated cells of palolo trochophores and *Toxopneustes plutei,* and of the swimming-plates of the ctenophore *Beroë* ceases in each case before NaOH enters. In NH_4OH, on the other hand, the cilia of palolo trochophores and *Toxopneustes plutei* remain beating long after the neutral red within the cells (not in the cilia themselves) is decolorized. The ctenophore swimming-plate in NH_4OH stops beating after the color change has begun but before it is complete, and the same is true for movement of the gills and tentacles of annelids and the tentacles of *Pennaria.*

The relation between penetration and cytolysis of marine eggs is of special interest. Every egg thus far tested (including, besides those already mentioned, *Fissurella, Cumingia,* and *Chætopterus*) has proved to be instantly penetrated by NH_4OH, so that the color change always occurs *before* the egg begins to swell or, indeed, before it is injured. The same is true of the amines. Cytolysis ensues later, after a certain interval.

As regards penetration and cytolysis by NaOH, there are four types of eggs. N/80 to N/500 alkali was used according to the natural resistance of the egg, which varies greatly.

1. Eggs like those of *Toxopneustes,* which may remain in N/80 NaOH for 6 minutes unchanged, at the end of which time swelling and color change both begin simultaneously and are completed almost instantly.

2. Eggs like those of the palolo, which may remain in N/80 NaOH for 8 minutes unchanged, at the end of which time the surface becomes irregular in appearance, the egg begins to swell slowly and to be decolorized, and in 5 minutes more is completely colorless.

3. Eggs like those of *Cumingia,* which may remain in N/320 NaOH unchanged for 6 minutes, at the end of which time they swell suddenly, but the granules do not become yellow for two minutes after swelling.

4. Eggs like those of *Holothuria,* which in N/40 to N/80 alkali, color change and swelling take place simultaneously but gradually (as in the palolo), but in N/160 to N/640 alkali the eggs become completely decolorized a considerable time before cytolysis occurs.

In NaOH swelling is practically always *coincident with or prior to* the color change; in the amines swelling always *follows* the color change. In NaOH cytolysis must be dependent on a change in the surface-layer of the egg, since it may take place before any appreciable amount of alkali penetrates. The probable nature of this change is, among others, an increase in permeability to the salts of sea-water produced by combination of NaOH with the *surface* proteids.

In all the preceding experiments the NaOH was dissolved in Mg-free sea-water. If dissolved in 0.6 M. NaCl instead of Mg-free sea-water, NaOH enters about six times as rapidly. In pure NaCl, the resisting power of the surface layer of the egg is greatly reduced, as compared with the balanced solution (Na, K, Ca mixture), a view advocated by R. S. Lillie and beautifully demonstrated by the recent experiments of Osterhaut.* In this connection it is interesting to note that in the medium which most closely approaches the normal, the condition of the surface is that of greatest impermeability.

Loeb has shown that KCN will prevent or diminish the toxic action of many substances, including NaOH, for the sea-urchin egg. The question arises whether it does so by preventing the entrance of the NaOH. The life of immature eggs of *Holothuria floridana,* stained in neutral red, into which NaOH may pass without producing cytolysis, is prolonged in the presence of KCN, but the KCN does *not* influence the rate of penetration of the NaOH. On the other hand, the life of eggs of *Chætopterus* or *Cumingia,* in which NaOH only enters after cytolysis is complete, is prolonged by KCN, as is also the rate of entrance of NaOH. Such a condition is certain to occur in eggs in which the color change only occurs after cytolysis begins. Whether NaOH would diffuse into sea-urchin's eggs during a prolonged stay in weakly alkaline solutions rendered innocuous by addition of KCN, I have not yet determined.

THE QUESTION OF NERVE FATIGUE.

Several years ago Dr. Mayer discovered that a nerve-impulse may be entrapped in a ring of the subumbrella tissue of *Cassiopea* so as to move around the ring continuously in one direction. Dr. Mayer was able to maintain the impulse for 6 days. I have repeated the experiment, in order to determine how long it is possible for the impulse to move under favorable conditions, because of its bearing on the question of nerve fatigue. The impulse in one ring was conducted for 11 days with no appreciable slowing in the rate. The average velocity was 46,472 mm. per minute, or about 67 kilometers per day. At the end of the 11 days, when the impulse stopped suddenly, it had traveled 737 kilometers, or 457 miles.

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* Science, n. s., XXXIV, p. 187. 1911.

The muscle tissue fatigued so that after twelve hours the amplitude was very much reduced. Handling the ring in changing water has no effect on the rate of conduction, but the contraction is increased. After 8 days the muscle contraction is hardly visible. On changing the water the impulse is generally slowed after this time.

During the day the velocity of nerve conduction is greater than during the night. This fact is possibly due to the variation in oxygen supply conditioned by symbiotic algæ in the subumbrella tissue.

Physiological Studies on the Protozoan Parasites of Diadema setosum, by Dr. Merkel H. Jacobs, University of Pennsylvania.

The object of these experiments was to determine how far, in the case of a number of forms of parasitic protozoa, presumably of different origin, inhabiting the same host, the similarity of their environment has brought about physiological similarity in the parasites. The method employed was to determine and compare the resistance of each of the forms in question to various artificially changed conditions. The protozoa chosen for the purpose were the ciliates parasitic in the alimentary tract of the large black sea-urchin, *Diadema setosum*. They are comparatively unspecialized forms, which are easy to obtain in large numbers, and are therefore suitable for the beginning of such a study. The writer intends to extend the results obtained by a series of similar experiments on some of the more specialized forms found in other animals.

The protozoan parasites of *Diadema* are chiefly ciliates, of which four kinds are by far the most abundant. These four forms are not closely related to each other and differ widely in size and structure. Since apparently none of them have been described or named, they are designated in these experiments, for purposes of convenience, by the letters A, B, C, and D. Form B seems to be present in almost, if not quite, 100 per cent of all adult diademas, C in about 75 per cent, D in about 40 per cent, and A in about 33 per cent. The number of individuals present is often very large. The parasites seem to be confined exclusively to the alimentary tract, and are found chiefly in the upper coil of the intestine. Very young diademas do not contain them and slightly older specimens, while sometimes showing forms C and D, and another form not found in the adult (?), do not seem to contain either A or B. None of the forms in question was ever found in sea-water nor in unrelated animals, although a careful search was made for them. In other genera of sea-urchins, however, they may occur in varying numbers. B was found rarely in *Toxopneustes* and *Echinometra*, and C on a number of occasions in *Toxopneustes*, while D seems to be present in every adult *Toxopneustes*, which probably is its true host, and rarely in *Echinometra*. A was never found outside of *Diadema*. A number of specimens of *Hipponoë* were examined for protozoan parasites, without results.

The experiments made to throw light on the physiological resemblances and differences of the forms in question dealt with the following points: (1) ability of parasites to live outside the body of the host; (2) ability to live in the body-fluid of other related animals; (3) ability to live in the body of the host after the death of the latter; (4) resistance to high temperatures; (5) resistance to CO_2; (6) resistance to H_2S; (7) resistance to decomposing proteids; and (8) resistance to acids and alkalies. The following results were obtained:

All of the forms experimented on can live for a certain length of time outside the body of *Diadema,* either in the body-fluid of the latter or in sea-water. Form A lives in sea-water only 2 or 3 hours, D about 24 hours, C a trifle longer, usually less than 30, while B lives for 2 or 3 days. The different forms therefore show considerable differences in their resisting powers, B being about 24 times as resistant as A.

The exclusion of air from a sea-water culture by boiling the water before using it and keeping the culture in a tightly sealed dish has a favorable effect on B, increasing its life to as much as a week, which is the longest period for which any of the four forms have been kept alive in artificial cultures. A, C, and D are scarcely affected one way or the other by this treatment.

The body-fluid of *Toxopneustes* seems to be toxic to the parasites of *Diadema* and *vice versa.* Placed in a few drops of *Toxopneustes* body-fluid, form A from *Diadema* died in an hour and a half, B in 3 hours, and C was living after 15 hours, but dead in 24. In the control culture in which the same forms were kept in the body-fluid of *Diadema,* both B and C were alive after 15 hours and B after 24. C therefore lives almost or quite as long in the body-fluid of *Toxopneustes* as in that of *Diadema,* while B lives something less than one-eighth as long. Form D from *Diadema* unfortunately was not available for this experiment. The same form from *Toxopneustes* was killed by the body-fluid of *Diadema* in 1 to 2 hours. There are good reasons for believing that mere differences in the concentration of the two body-fluids can not account for the facts observed, but that chemical rather than physical factors are involved.

The four parasites behave differently after the death of the host. D disappears as a rule in 12 to 15 hours, A in less than 20, and B and C often live as much as 24 hours. None of the forms, however, have been found living after 30 hours; a diminution in the numbers of all can frequently be detected in less than 12.

A is killed by a temperature of 39.5° C., while B and C both succumb at about 40.5°. Figures for D are not available.

The forms in question show their most striking differences in their resistance to chemicals. Experiments were made with a number of substances which they either might be expected to encounter in nature (CO_2, H_2S, decomposing proteids), or which were at least representatives of a class of such substances (H_2SO_4 and KOH as representatives of acids and alkalies).

Placed in a gas-chamber filled with pure CO_2, D is killed in 3 to 4 minutes, A in 5 to 6, C in about 15, and B in 45 to 60. B is therefore about 15 times as resistant as D. Water saturated with CO_2 has a similar effect.

Treated in the same way with H_2S (which can be detected in the intestine of *Diadema* soon after death), C is killed in 1 to 2 minutes, D in about 3, A in 3 to 4, and B in 10 to 15. B is therefore 8 to 10 times as resistant as C.

Of an infusion made by allowing fragments of *Diadema* tissues to decay in sea-water for 3 days, 5 drops were added to 10 drops of a culture containing the four forms in question. B was killed almost instantly, certainly in less than 5 seconds, A in 10 to 60 seconds, D in 20 to 25 minutes, and C only after about 2 hours. C is therefore 1,500 times as resistant as B.

Treated with H_2SO_4 in the proportion, 1 drop of N/10 acid to 5 of culture fluid, A is killed in about 5 seconds, D somewhere between 5 and 30, the exact time not being noted, C in about 30 seconds, and B only after an hour and a quarter. B is therefore 900 times as resistant as A and 150 times as resistant as either C or D.

The effect of KOH of the same strength is quite different. A is killed in 2 minutes, D in something less than three-quarters of an hour, B in about 1 hour, and C in 3 to 4 hours, C being about 100 times as resistant as A and 3 to 4 times as resistant as B.

The general result of these experiments is to show a surprising difference in the resisting powers of the parasites of *Diadema* to various changed environments. In some cases the most resistant form may live several hundred times as long as the least resistant. Furthermore, a form which is strongly resistant to one condition may be only feebly so to another, and *vice versa.* For example, B is 8 to 10 times as resistant to H_2S as C, but 1,500 times *less* resistant to the products of proteid decomposition. C is more resistant to CO_2 than A or D, but less resistant to H_2S. A, C, and D are 24 to 450 times more resistant to KOH than to H_2SO_4, while B is somewhat *less* resistant, etc. These and other similar facts that might be adduced show that each of the forms in question has certain physiological traits that are almost as characteristic and well-marked as its morphological ones. Furthermore, so far as the evidence obtained from these experiments goes, there is no reason to suppose that the similar habit of life in the parasites of *Diadema* has succeeded in bringing about physiological similarity, except in such adaptive characters as are necessary for existence within the same host.

Report upon the Dimorphic Spermatozoa of Marine Prosobranchs, by E. E. Reinke, Princeton University.

The most accurate and complete description of the development of the dimorphic spermatozoa found among certain marine and fresh-water prosobranchs has been given by Meves in the case of *Paludina vivipara.* He has named those spermatozoa which function in the ordinary way "eupyrene" and the others "oligopyrene," and has described the growth period of the spermatocyte as showing the earliest differentiation, in their development, between the two kinds of male sex-cells, while the spermatogonia or their ancestors are common to both.

This differentiation, however, can be traced further back. I have observed in the testis of both *Paludina* and *Urosalpinx cinerea,* at an early stage of their seasonal development, that the "Basalkerne" of Platner are in some cases swollen into tremendous proportions, while in others the already swollen nuclei are in various stages of fragmentation. These nuclear fragments round out into ordinary nuclei and begin to push out from the syncytium in which they lie into the interior of the lobule of the testis, taking with them a covering of cytoplasm, which, however, retains a connection with the syncytium. The cells thus formed become pear-shaped and grow rapidly, so that they can readily be distinguished from the eupyrene spermatocytes by their greater size. In *Paludina* the development of the oligopyrene spermatozoa from these cells occurs as described by Meves.

In the summer of 1910 I obtained a few specimens of *Littorina nebulosa* from Jamaica; and, upon sectioning them, I found that although only eupyrene spermatozoa are present, there is a cell very similar to the oligopyrene spermatocyte of *Paludina.* This develops into a nurse-cell to which spermatozoa become attached and which, together with the latter, moves into the sperm-duct. It was with the purpose of studying these cells in a live condition, and also of collecting whatever material I could for the study of oligopyrene spermatogenesis, that I went to Port Royal, Jamaica.

Kingston Harbor abounds with many prosobranchs, among which are at least three species of *Littorina.* After a thorough examination I found that those snails which live above water-mark for any length of time do not have oligopyrene spermatozoa, and I think it may be held in general to be true that the dimorphism of the male sex-cells among prosobranchs occurs only in some of those which live below the surface of the water. *Urosalpinx* may constitute an exception, but if it is not covered with water it is under a moist stone or other object and not exposed to view. Among the snails which have oligopyrene spermatozoa and are easily obtainable in the vicinity of Kingston Harbor are *Murex* sp., *Pteroceras* sp., and several species of *Strombus.* My work, however, was confined to *Littorina* and *Strombus.*

The contents of the sperm-duct of *Littorina nebulosa,* when diluted with sea-water, appear under the microscope as a great number of spheres, to each of which is attached a tuft of spermatozoa. These spheres are composed of a number of large granules inclosed in a membrane, and among them is a very degenerate nucleus; this may be demonstrated by straining intra vitam with methylene blue. On one side there is an agglutinous pabulum into which are inserted the heads of the spermatozoa. The first movement to be seen is a rhythmical and uniform beating of the entire tuft; this sends the nurse-cell forward. Presently the tuft spreads and then each spermatozoon beats independently of the others. In case two or more tufts meet, the spermatozoa become entangled with each other and the nurse-cells are drawn together and held by the sticky substance into which the former are inserted. From a mass such as this the tails of the spermatozoa will be seen protruding on all sides and beating like cilia. They will remain alive in this condition for several hours.

Up to a very late stage in their development these cells retain a connection, by means of a long stalk, with the wall of the testis. Small granules of yolk matter pass up the stalk and are dissolved in the cytoplasm of the cell. The nucleus soon begins to degenerate and various areas of the cytoplasm are seen to differentiate into large granules. These finally fill up the body of the cell, and the nucleus, which by this time has the appearance of an empty, crumpled shell, is pushed to one side. Probably as the stalk snaps it draws up a large number of spermatozoa after it towards the cell-body. Although at present I can not make the assertion that these cells originate in the same way as I have described for the oligopyrene spermatocytes of *Paludina,* the evidence I have seen seems to indicate that to be the case. As to their function, they undoubtedly serve as nurse-cells to the spermatozoa while the latter are in the sperm-duct. Sections of the winter testis of *Littorina rudis* show the sperm-duct full of spermatozoa and of nurse-cells which are in a more or less exhausted condition.

While at Port Royal, with ample material at hand, I had an excellent opportunity of making a thorough study of the oligopyrene spermatozoon of *Strombus* in a live condition. Bróck has described and figured it, but not quite accurately. The spermatozoon in this case is larger and of a more complex structure than that of either *Paludina* or *Urosalpinx.* The head is wide and sharply pointed and provided with a long protoplasmic rostrum, while the tail is narrow and blunt. The cell-body is cylindrical and tapers at either end, but its breadth is considerably increased by the presence of two undulating membranes, which pass down from the rostrum on either side and fuse at the posterior end. The interior of the cell is filled with cubical bodies, which are larger in the middle and smaller at either end. These bodies disappear either wholly or in part after the spermatozoa have been in sea-water about two hours. They seem to go into solution and in their place is left a brownish semi-fluid, granular substance in which may still be seen the hexagonal outlines of the bodies.

In sea-water the eupyrene spermatozoa soon come to rest, but the oligopyrene continue active for about two hours. The latter are equipped with neither cilia nor flagella, and their movement is caused solely by the undulating membranes. At first large, slow waves pass down the membranes alternately on either side; later the waves become shorter and more rapid and pass down both sides simultaneously. By this time, however, movement of the spermatozoon itself has ceased, as it very soon attaches itself by means of the rostrum. As soon as the cell flattens out a number of overlapping folds are to be seen in the membranes; these are due to the fact that the membranes are not flat but wavy. The reaction of these membranes to salt solutions isotonic with sea-water are uncertain; it is not ciliary and it gives some indication of being neuro-muscular. In NaCl movements of the membranes may be observed at the end of five hours, while in $MgCl_2$ they were inhibited if anything.

A subsequent study of the testis of *Strombus* has yielded some interesting facts. In the first place, the oligopyrene spermatocyte develops directly into the spermatozoon. I have been able to find no indications of a division or divisions such as occur in *Paludina,* nor have I seen any two spermatids which could possibly be construed as daughter cells resulting from such a spermatocytic division. I have not seen all the stages of the transformation, but it appears to occur in this way: The nucleus of the large and easily recognizable oligopyrene spermatocyte breaks up into a great number of vesiculated fragments (chromosomes?), which come to lie scattered throughout the cell-body. The cell then begins to elongate and the nuclear fragments to degenerate. Later on a thick bundle of fibers is to be seen running through part of the cell-body and extending beyond the cell-wall as flagella. These probably arise from a large centrosome, which is visible before the nucleus breaks up, but whose subsequent fate I have not as yet succeeded in tracing. At all events, long before the spermatozoon has reached maturity, both the bundle of fibers and the flagella have disappeared as such, fusing to form the undulating membranes and the rostrum. The development of the cubical bodies is very similar to that of the granules in the nurse-cells in *Littorina nebulosa.* They begin to appear about the time of the disappearance of the flagella and are entirely of a cytoplasmic origin.

The evidence furnished by *Strombus* only goes to strengthen my belief that the so-called oligopyrene spermatozoa are motile nurse-cells which are quite comparable to those of the *Littorinæ,* if not entirely homologous with them, but which only function as such in the seminal receptacle of the female. An examination of the seminal receptacle of *Urosalpinx* in midwinter showed it to be full of both kinds of spermatozoa, indicating that the period of copulation precedes that of oviposition by a considerable length of time. Granting that in all cases one year's crop of spermatozoa fertilizes the next year's crop of eggs, a premise which I believe to be true, then in the case of *Littorina* (probably all species) one would expect the period of copulation to be nearer that of oviposition than it is among those prosobranchs which have motile nurse-cells (oligopyrene spermatozoa), since here the nurse-cells function in the sperm-duct for at least the greater part of the winter.

Report of Preliminary Investigations on the Marine Denitrifying Bacteria, made at Port Royal, Jamaica, and at Tortugas during May and June 1911, by G. Harold Drew, Christ's College, Cambridge, England.

It appears to be well established that the plankton of tropical and subtropical seas is far less in quantity than that found in colder waters.

The zoo-plankton depends ultimately for its food on the phyto-plankton; hence any factor limiting the growth of the phyto-plankton which was capable of exercising its influence in tropical and not in temperate or arctic waters might offer an explanation of this phenomenon. It has been shown by various investigators that this factor is not temperature, light, or salinity, and it has been suggested that the explanation may lie in the relative deficiency in tropical seas of the nitrates or nitrogenous compounds which are so essential for all plant life. A matter of common observation in support of this view is the remarkable scarcity of algal growth in the shallow waters of tropical shores as compared with that in temperate regions, and the fact that in the Tropics, wherever sewage or other nitrogenous waste is poured into the sea, a free growth of algæ is found.

At present no reliable and accurate chemical method of estimating the combined nitrogen in sea-water exists; hence the above theory can not be directly put to the test. On the other hand, the existence of denitrifying bacteria in temperate waters has long been known, and it would seem a fair deduction that should this bacterial destruction of nitrates take place with greater intensity and completeness in tropical than temperate waters, an explanation of the relative scarcity of phyto-plankton in the former would be offered. It was with the object of investigating this question that the present work was undertaken.

In Jamaica a measurement was made of the rate of denitrification in fluid culture media inoculated with samples of sea-water, but isolation of the bacteria on solid media was not attempted. The following method was employed:

Samples of sea-water were collected in sterilized stoppered bottles, from the surface and from depths of 3 and 6 fathoms, from positions about 5 miles from shore, where, from a consideration of the wind and tide, the water was probably under truly oceanic conditions and unaffected by the neighboring land. 10 c.c. of these samples were added to 1,000 c.c. of a modification of Gran's medium (see "Studien über Meeresbacterien," by H. H. Gran, Bergens Museums Aarbog, No. 3, 1901). This culture fluid was sterilized in glass flasks, and has the following composition:

Potassium nitrate (KNO_3)	0.5 gram.
Sodium phosphate (Na_2HPO_4, $12H_2O$)	0.25 gram.
Calcium malate ($C_2H_3(OH){<}{COO \atop COO}{>}Ca$)	about 5.0 grams.
Sea-water	1,000.0 c.c.

Calcium malate is only slightly soluble in water, so can be added in excess.

The reduction of the nitrate to a nitrite was tested for by the addition of 5 c.c. of 10 per cent sulphuric acid and 2 c.c. of a 1 per cent solution of metaphenylene diamine hydrochloride to 25 c.c. of the culture. The production of a brown coloration (due to the formation of Bismarck brown) is an indication of the presence of a nitrite, and is an extremely delicate reaction.

The formation of ammonia was similarly tested for by the addition of 5 c.c. of 10 per cent potassium hydrate and 5 c.c. of Nessler's reagent; the white precipitate formed on the addition of the potassium hydrate does not appreciably interfere with the test, though it renders it somewhat less delicate.

The cultures were kept in a moderate light, and the room temperature varied from 25° to 31.5° C. The average temperature during the growth of each culture was noted.

In a typical culture made from surface-water, and for which the average temperature was 29° C., the first indication of the formation of a nitrite, as given by the metaphenylene diamine reaction, appeared after 27 hours; after 38 hours the brown color produced in this reaction was very intense, the culture became cloudy, and, on testing with Nessler's reagent, slight ammonia formation was apparent. After 48 hours the culture became very cloudy and a scum of bacterial growth developed. The nitrite and ammonia reactions remained unaltered. After 63 hours the nitrite reaction was somewhat less marked, the ammonia reaction was unaltered, and bubbles of gas began to appear. After 72 hours many bubbles of gas were being produced, and the nitrite and ammonia reactions were very slight. After 86 hours the bubbling had ceased, and no nitrite or ammonia was present in the culture. Testing the culture for nitrates by the brucine and diphenylamine reactions then showed that no nitrate was left in the solution.

In the absence of a gas-analysis apparatus the nature of the gas evolved could not be determined, but considering that it was non-inflammable, did not turn lime-water milky, and that the nitrate originally present had been destroyed, it seems strongly probable that this gas was pure nitrogen. Thus in 86 hours 0.5 gram of potassium nitrate had been decomposed by bacterial growth. If a further 0.5 gram of potassium nitrate were then added it was rapidly decomposed, and this could be repeated many times until the other constituents of the culture medium were used up.

It was found that the rate of denitrification varied somewhat with the temperature, and that in cultures kept at a temperature of between 10° and 12° C. no growth or denitrification occurred. The denitrification was always more rapid in cultures from water taken from a depth of 3 or 6 fathoms than from the surface. It was also more rapid with samples taken from the thick muddy water of a mangrove swamp, where organic matter was plentiful.

The bacteria present in the cultures were very minute, actively motile bacilli with rounded ends.

The results of similar experiments performed with samples of water taken from the English Channel near Plymouth, in the autumn of 1909, show that there the process of denitrification is very much slower, and was never complete at the room temperature. The first trace of the formation of a nitrite in cultures in the modified Gran's medium, as detected by the metaphenylene diamine reaction, occurred about the fifth day, and a large proportion of nitrite always remained, even in the oldest cultures.

Samples of water taken from the neighborhood of the Tortugas showed about the same rate of denitrification in cultures as those from Jamaica.

Cultures were made on various solid media, and pure cultures were isolated. The chief media employed were:

1. Potassium malate ($C_2H_3OH<\substack{COOK \\ COOK}>$)	1.0 gram.
Sodium phosphate (Na_2HPO_4, $12H_2O$)	0.25 gram.
Potassium nitrate (KNO_3)	0.5 gram.
Sea-water	1,000.0 c.c.
Agar-agar	12.0 grams.

The medium was only filtered through glass wool, so that a very slight floccular precipitate of calcium phosphate was retained.

2. Petone	2.0 grams.
Potassium nitrate (KNO_3)	0.5 gram.
Sea-water	1,000.0 c.c.
Agar-agar	12.0 grams.

By plating samples of surface-water from various positions round Tortugas as far as possible removed from influence of the land, and collected on sunny days, an average of 14 colonies per 1 c.c. sea-water was obtained. These colonies appeared to be of two kinds when grown on peptone agar, one much more plentiful than the other. Subcultures made from these colonies in Gran's medium showed that the bacteria forming the most common type of colony produced an active denitrification, while the others grew very slowly in this medium and produced no denitrification.

The characteristics of the denitrifying form are as follows:

On the potassium malate or peptone agar media colonies are visible as minute white specks after 6 to 8 hours when the room temperature averages 29.5° C. After about 18 hours the colonies are well developed. They are white in color; circular, but with finely irregular outline, and have a granular appearance. Superficial colonies are much elevated at first, but, as growth proceeds, spread rapidly over the surface of the agar. Deep colonies remain small, circular, and discrete.

Growth is somewhat more rapid on peptone agar than on the potassium malate agar, and the older colonies develop a brownish tinge in the center when growing on the former medium. On gelatin peptone (0.5 per cent peptone in sea-water and kept at between 20° and 25° C. to insure the medium remaining solid) growth was very slow. In stab cultures growth proceeded slowly from the surface downwards, leaving a funnel-shaped depression of liquefied gelatin.

Acid formation occurs in dextrose, levulose, mannite, and cane sugar, but not in lactose media.

Growth is inhibited at a temperature of 10° C., but takes place slowly at 15° C.

Growth is much retarded by exposure to bright sunlight, but the bacteria are not killed by a 10 hours' exposure.

The bacteria are facultative anaërobes, but growth under anaërobic conditions is very slow.

In Gran's medium growth is rapid, but no growth occurs if the potassium nitrate be omitted, or if the calcium malate be replaced by calcium carbonate. Growth in a pure solution of peptone in sea-water is very slight, but becomes abundant if potassium nitrate be added, when denitrification quickly ensues. The most rapid growth was produced in sea-water containing 0.2 per cent peptone, 0.1 per cent potassium malate, and 0.5 per cent potassium nitrate, and in this clear medium a slight floccular precipitate, presumably of calcium salts derived from the sea-water, was soon formed. Growth was also rapid at first in a solution of 0.5 per cent potassium malate, and 0.05 per cent potassium nitrate in sea-water, but in this medium growth apparently ceased after a few days and denitrification was never complete. A slight precipitation occurred, and the solution was found to have very definitely increased in alkalinity. It was this increase in alkalinity and consequent cessation of growth of the bacteria that led Gran to employ a calcium instead of a potassium salt in his culture medium, as in this way the calcium carbonate formed by the bacteria from the organic calcium salt is removed from the sphere of action by precipitation.

In its cultural reactions this bacterium is very similar to certain denitrifying forms found in the English Channel; the chief points of difference consist in its much greater denitrifying power and the relatively higher temperature necessary for its growth, by which it would be prevented from spreading into more temperate waters, unless it is capable of acquiring an adaptation to altered conditions of temperature.

Since the calcium salt of a simple organic acid is a sufficient source of organic food for these denitrifying bacteria, it would seem probable that they could thrive in sea-water containing the products of decomposing vegetable life, provided that the nitrate supply and conditions of light and temperature were suitable. Such conditions should be especially well fulfilled by the drainage into the sea of a well-wooded country composed of calcareous rock, and the soluble organic calcium salts would be precipitated as calcium carbonate by the action of the bacteria. In addition, the elimination of the acid radicle from the nitrate in the process of denitrification, by whatever stages it may occur, must leave the alkaline base free to destroy the normal equilibrium of the salts in sea-water, and by increasing the alkalinity would also result in the precipitation of calcium carbonate.

The formation of beds of fine unorganized chalky mud in certain places off the southern Florida Keys may possibly be explained in this way, and it is conceivable that some such bacterial action may have played a part in the formation of some chalk and oölitic limestone beds in geologic times.

The characteristics of the scarcer non-denitrifying form of bacterium found on the agar plates are as follows:

Growth on the potassium malate agar medium is very slow and indefinite. On peptone agar growth is somewhat slower than in the case of the denitrifying form. On the surface circular, cream-colored colonies are formed, having a brownish center; the edges are smooth and regular, and the colony remains discrete and does not tend to spread over the surface. The deep colonies are smaller and usually ovoid in shape, and of a somewhat darker color than those on the surface.

No growth was obtained on gelatin media.

Acid formation occurs in dextrose and levulose, but not in cane sugar, lactose, or mannite media.

Growth takes place slowly at 10° C. No visible growth occurred at 0° C., but cultures were not killed by 24 hours' exposure to this temperature.

Growth is retarded by light, and cultures are killed by 4 hours' exposure to bright sunlight.

The bacterium is a strict aërobe.

Free growth takes place in Gran's medium, but is much slower than in the case of the denitrifying form; no growth occurs if the potassium nitrate be omitted, though no denitrification results if it be present.

Many attempts were made to discover whether this bacterium had any nitrifying or denitrifying action in cultures, but uniformly negative results were obtained. Nitrites were neither oxidized to nitrates nor reduced to ammonia or free nitrogen, and ammonium salts were unaffected. No growth was obtained in any culture medium that did not contain at least a trace of nitrates, so it was not practicable to ascertain whether the bacterium had a nitrifying action with the apparatus available.

On one occasion samples were obtained from various depths down to 90 fathoms at a point in the Gulf Stream 25 miles south of Tortugas. For this purpose glass flasks of about 300 c.c. capacity with narrow recurved drawn-out necks were exhausted and sealed; they were then lowered in an apparatus by which the extremity of the neck could be broken off at any desired depth by sending a messenger down the sounding wire, when the flasks became completely filled with water. These samples were plated and counted with the average results shown in the table.

Depth.	Denitrifying form.	Non-denitrifying form.	Total.
0	9	2	11
10	25	4	29
40	2	2	4
60	5	3	8
90	5	6	11

If any deductions can be made from one series of observations, it would seem probable that the non-denitrifying bacteria are a deep-water form, and this would be upheld by the ease with which they are killed by exposure to sunlight. On the other hand, the denitrifying bacteria would appear to be a surface form reaching their maximum a little below the surface. This would be upheld by the results obtained in Jamaica, in which it was shown that denitrification occurred much more rapidly in cultures made from samples collected from depths of 3 and 6 fathoms, and possibly explained by the fact that the growth of the bacteria is inhibited by strong light.

On August 7, 1911, two samples of water were collected in the lagoon of the Marquesas Islands, 40 miles east of the Tortugas. These samples were obtained near the eastern entrance to the lagoon, while the tide was still ebbing but nearly low. The bottles were sent to Plymouth, England, where they were studied with the following result:

Sample of Water from Marquesas Keys.

The salinity of the lagoon water was low, being only 33.95.

Plated on peptone agar, 1 c.c. = 800 colonies (average of 5 plates). Colonies appear all of same kind.

Agar.—After 24 hours (at 75° F.) colonies are white, circular, with finely irregular outline. Superficial colonies are considerably elevated, slightly granular, and spread rapidly. Deep colonies remain small and circular. Old cultures become yellowish and the color may spread through the agar.

Gelatin stabs.—Growth mostly superficial, with liquefaction; very slight growth in deeper parts of stab.

Glucose, peptone, neutral red medium = acid formation.
Cane sugar, peptone, neutral red medium = acid formation.
Mannite, peptone, neutral red medium = acid formation.
Lactose, peptone, neutral red medium = no acid formation.

Rapid growth and denitrification in the modified Gran's medium.

Rapid growth in a medium consisting of calcium succinate 1.0 gram (soluble), potassium nitrate 0.5 gram, and sea-water 1,000.0 c.c., with production of thick, milky appearance, due to extremely finely divided particles of calcium carbonate, so fine that they will not settle.

To such a culture a trace of very finely powdered hydrated calcium sulphate or fine sand was added. This resulted in the formation of a precipitate, which, on microscopical examination, could be seen to consist of finely laminated concretions, some of which appeared to have a particle of calcium sulphate or sand as a nucleus. The concretions were soluble in dilute hydrochloric acid with evolution of carbon dioxide. These concretions bear a resemblance to those of some oölitic limestones, and the experiment suggests the manner in which such oölites may have been formed.

The bacteria which cause the formation of these concretions seem to be the same as those found at Tortugas and Jamaica.

Bacteria from depths ranging from the surface to 80 fathoms from 70 miles west-southwest of Ushant, France, on August 20, 1911, appear to be all of one and the same kind, and in cultural reactions to be precisely similar to the Tortugas and Jamaica denitrifying form, with the exception that acid formation does not occur with cane sugar.

Denitrification was relatively slow, the first trace of nitrite appearing only after 96 hours at 75° F., and all nitrite was never destroyed.

These observations suggest that the bacterial denitrification in tropical seas is far more active than in temperate regions, and if this can be substantiated by future work it would offer an explanation of the relative scarcity of plankton in the Tropics. As it at present stands, the investigation can at most be considered to offer a mere indication of the part played by bacterial growth in the metabolism of the sea. To obtain a real insight into the question, it would be necessary to make more extensive bacterial and chemical observations in tropical, temperate, and arctic waters, and more especially to make a study of the bacterial flora of the deep sea in some spot where considerable depth, unaffected by currents, could be obtained. The possibility that bacterial growth plays an important part in causing the precipitation of certain bottom deposits in coastal waters, and conceivably also in the deep sea, is a subject well worthy of investigation.

A point not yet touched upon is the origin of the nitrate supply in the sea. Nitrates are absorbed by diatoms and the phyto-plankton in general in the course of their growth, and are presumably built up into complex nitrogenous compounds within the plant. If these compounds on the death of the plant are broken up and the nitrogen again rendered available for use in the form of nitrates, a series of reactions must be gone through which may well be performed by bacterial agency, and this also applies to the waste nitrogenous products of animal metabolism.

In addition, it has been shown that nitrates are actually decomposed by the denitrifying bacteria, and they would thus tend to keep the nitrate concentration down to the level necessary for their own existence, and would come into competition for this essential with other forms of plant life. If the bacteria are successful in liberating free nitrogen from nitrates, as seems probable from the experiments in cultures, it follows that there must be some source of nitrates in order that the concentration in the sea may remain constant. The existence of symbiotic nitrifying bacteria on some of the algæ around the shores of the North Sea has been demonstrated, and it seems possible that forms having a similar nitrifying action in the open sea remain to be discovered.

Report upon Investigations carried on at the Tortugas Laboratory during 1911, by L. R. Cary, of Princeton University.

REARING OF ZOANTHELLA.

Continuing the experiments started during June 1910, I collected a considerable number of specimens of *Zoanthella,* mostly *Z. semperi,* and attempted to rear them to the adult stage. A single specimen became attached to the bottom of the dish in which they were kept, and changed its shape until it had become about one-eighth of its original length and three times its original diameter at the base. The oral end retained practically the same size as when it was in the free-swimming condition, and became very retractile. The mouth-opening increased in diameter to about three times its former size. The oral disk became broader and flattened. Around the border of the oral disk, at the point where it joins the column-wall, there was formed a prominent ridge, which rose for a considerable distance above the flat part of the disk. This ridge was nearly continuous, showing no indications of elevations and depressions, which would mark the beginning of the growth of tentacles, except at one point, where the ciliated band had formerly been situated along the side of the larva. When this specimen had been kept under observation for 10 days from the time of its attachment a piece of the glass dish to which it was attached was cemented to a tile and put out on a shallow reef near Loggerhead Key.

A number of other larvæ, when they had shown no indication of transforming after having been kept in aquaria for two weeks, were subjected to experiments in which the amount of light admitted to the jars was controlled. One lot of the larvæ was kept in the dark for 72 hours and then brought back into the full light as before. All of these specimens had, when brought into the light, lost most of their algal cells (Zooxanthellæ), which had come out from the body of the larva and settled on the bottom of the dish. Of the 8 specimens in this lot, 5 underwent their transformation within 3 days after having been brought back into normal conditions as regards the lighting. The 3 remaining individuals never transformed, but showed a broadening of the oral disk area and an increase in the size of the mouth, while still retaining the longitudinal band of cilia in an active condition.

The specimens which went through an otherwise (apparently) normal transformation were unable to attach themselves. They rested on the bottom of the containing vessel, but with one exception remained with the pedal disk uppermost. They were finally inclosed in spirals made from silver wire which would hold them in their normal position. One specimen from this lot, while still within the wire ring, was cemented on a tile and put out in the moat at Fort Jefferson. The remaining specimens were brought to Princeton and are at present in the salt-water tanks of the vivarium.

Other lots of larvæ were kept in jars the sides of which were covered with light-proof paint, while the light admitted through the top or bottom was made to pass through blue glass. None of the specimens thus treated transformed. Three specimens, which were left without changing the water for 3 days in a dish containing about 300 c.c. of sea-water, underwent a partial transformation, such as has been described for some of the specimens kept in the dark for 3 days. These specimens, together with some others which had been recently taken in the tow, were brought to Princeton for further observation.

OBSERVATIONS ON GORGONIANS.

A series of measurements to ascertain the rate of growth of several species of gorgonians was begun in June 1910. In so far as was possible, on account of the weather conditions, the specimens for which measurements were recorded at that time were remeasured on January 10 to 12, 1911, when the writer visited Tortugas in company with Dr. Mayer. The same colonies were measured again on July 22, 1911.

The following table shows the actual lengths of a number of gorgonians on a single coral-head at the dates when measured and the percentage of increase in approximately one year:

Species and specimen.	June 1910.	Jan. 10-12, 1911.	July 22, 1911.	Per cent of increase.
	mm.	*mm.*	*mm.*	
Gorgonia flabellum:				
Specimen 1	100	135	150	50
2	100	138	150	50
3	70	100	145	107.14
4	300	(*)	330	10
5	150	(†)	219	46
Plexaura flexuosa:				
Specimen 1	80	105	135	68.77
2	150	(†)	155	3.3
3	50	65	83	66.6
4	245	(†)	269	9.7
5	115	150	163	41.39

* Could not be measured.
† Not measured.

The measurements made in January 1911 are incomplete and to a greater extent inaccurate, on account of the difficulties caused by the roughness of the water. Specimens 1, 2, and 4 of *G. flabellum* had been exposed to the air at an unusually low tide on June 6, 1910, and as the result the uppermost end of each colony was killed. When they were measured in January 1911 all evidence of this injury had disappeared.

With all of the other colonies measured the results were, in general, the same. Those which were smallest when first measured showed the largest percentage increase in size, while the smallest increase, actual as well as by percentage, was found in those colonies which were largest when first measured.

During the present summer the measurements were extended to include a much greater number of colonies of the two species previously mentioned, and to specimens of 5 other forms. Specimens of all the forms were cemented to tiles, measured, photographed, and fastened by iron pins on the reef near Loggerhead Key. On one small reef all of the colonies of *Gorgonia flabellum, G. acerosa,* and *Plexaura flexuosa* (148 in number) were measured and classified in arbitrary groups, according to size, as follows: Group 1, 0 to 6 inches; group 2, 6+ to 12 inches; group 3, 12+ to 18 inches; group 4, 18+ to 24 inches; group 5, 24+ to the largest specimen found. The percentage of each size for each of the three species is shown in the following table:

Species.	Group 1.	Group 2.	Group 3.	Group 4.	Group 5.
	per cent.	*per cent.*	*per cent.*	*per cent.*	*per cent.*
G. flabellum	7.35	36.76	30.88	16.17	8.82
G. acerosa	0.0	11.1	38.89	22.22	27.78
P. flexuosa	9.68	22.58	22.58	37.09	8.06

On the same area of reef the location of 23 dead colonies could be determined. With three exceptions, all of these skeletons were covered by a growth of living *Millipora alcicornis.* When a colony had been only a short time dead the *Millipora* conformed to the shape of the original gorgonian colony, even showing the meshwork of the skeleton of *G. flabellum.* In other instances the presence of the gorgonian skeleton within the *Millipora* colony could be demonstrated only after some of the projections on the latter colony had been broken off, when it would be found to contain a piece of gorgonian skeleton as a central axis.

The percentages of specimens of each different size, as shown in the table, when considered in relation to the rate of growth, seems to indicate that the norm of size for some species is reached within a comparatively few seasons. *Gorgonia acerosa,* on the other hand, would seem to have a more regular increase in size with a longer growing-period than the other species listed, as seen by comparing the figures in the fifth group of the last table. The comparatively small number of skeletons of dead colonies found on the reef indicates that the death-rate is very low. The fact that the skeletons, especially when covered by *Millipora,* will persist for a number of years in a recognizable condition makes it appear certain that the life of a gorgonian colony must extend for a considerable period after the norm of size has been reached.

REGENERATION EXPERIMENTS.

In the course of my work during the summer of 1910 it was observed that many colonies of the different species of gorgonians had undergone injuries of greater or less extent, and in order to determine the capacity for and rate of regulatory growth the following experiments were undertaken:

The species used for most of the experiments were those for which the greater number of measurements had been made—*Gorgonia flabellum, G. acerosa,* and *Plexaura flexuosa.* All of the operations were extensive, involving the cœnenchyme, and frequently the skeleton as well as the polyps.

The following table shows the nature of the operation and the general results for a few of the experiments:

Species and specimen.	Operation, June 1910.	Recovery, Jan. 1911.	July 1911.
G. flabellum:			
Specimen 1...	One-half cut from each leaf (longitudinally).	Healed; no regeneration.	No lateral growth.
2..	Split lengthwise into 5 pieces.	Edges healed	¼ inch of lateral growth.
3..	Circular pieces cut from leaf.	Healed around cut.......	¼ inch of in-growth of new tissue.
4..	Cut back one-half; 6 inches remaining.	Healed over and had grown to 7.5 inches.	9.5 inches long; blade had become rounded at upper end.
P. flexuosa:			
Specimen 1..	Side branches cut off; central ones slabbed on one side, exposing the skeleton.	Had healed over the denuded areas and new polyps were coming in on the "scar-tissue."	Polyps now cover denuded areas; new branches (8) appear on stumps of cut branches.
2..	Cut back from 11 inches to 6 inches.	Ends of branches healed over; had grown to 7.25 inches.	Now 10 inches high.
G. acerosa.......	One side of all branches trimmed and slabbed.	No new branches; scar-tissue covers all wounds; no polyps on scar-tissue on larger branches.	Polyps have appeared over scar-tissue on all of the smaller branches; the larger branches have scar-tissue with no polyps.

Pieces of the regenerating branches of *Gorgonia acerosa* were preserved when the reef was visited in January 1911 and sections were cut and studied.

In *Gorgonia* there is always formed a complete layer of cœnenchyma over a denuded area, which remains free from polyps for some time. The entodermal canals keep pace with the formation of the other tissues, but it is considerably later that the bud-like swellings of the canal, which mark the points of origin of new polyps, make their appearance. They always follow the same sequence as that shown in the formation of new tissue over a denuded area, appearing first at the periphery nearest to the older polyps. The formation of new skeletal tissue at the end of a cut branch takes place very slowly at first. After the new rod of skeletal tissue has attained a diameter equal to that of the older portion the elongation of the branch takes place rapidly. If the living tissue is removed from the skeleton about the base of a colony, there is, so far as my observations show, no down growth of tissue from the cut surface above the denuded stem.

EFFECT OF THE HURRICANE OF OCTOBER 17, 1910, ON THE ALCYONARIAN FAUNA ABOUT TORTUGAS.

The hasty observations made in January 1911 showed that as a result of the hurricane of the previous October there had been a great destruction of gorgonians on the reefs about Tortugas. On the east shore of Loggerhead Key, the only one visited at this time, many specimens of some five or six species of gorgonians were found thrown up on the beach along its entire length. At that time no estimate of the number cast up was made, nor was the area of reef visited sufficient to give conclusive evidence of the proportion of colonies carried from their natural location. In July 1911 the observations on these points were extended to an extensive area of shore-line and submerged reefs.

At one point on the inside of the east reef, near Bush Key, the gorgonian skeletons were counted over a strip of beach 112 yards in length, where there was a windrow, perhaps a yard wide, made up of the skeletons. The number of skeletons in a linear yard (practically a square yard) was 75.7 as the average for ten counts made at roughly equal distances through the above-mentioned distance, or approximately 8,500 colonies. This area showed very clearly that the most destructive part of the storm came from nearly northeast. On the outside of the reef, in the direction indicated by the wash of the storm, only two living colonies of gorgonians were found for as far offshore as the water was sufficiently shallow to allow one to wade about over the reef. Gorgonians were growing abundantly over this area when it was visited in 1910, so the destruction had been almost complete. That the greater number of the colonies found in the windrow on the beach had come from this shallow-water area was shown by the fact that in the deeper water on the outer portion of the reef there was little evidence of the lessening of the number of colonies below the normal number for such locations, where the colonies are always comparatively scattered, never forming dense "thickets," as they do on the reefs in shallow water. The very shallow water on the outside of the reef contained a considerable number of skeletons of *Gorgonia flabellum* and *Plexaura flexuosa*, which had been broken off from their supports or carried away from their original location while still attached to a good-sized piece of coral rock. Apparently these specimens had reached their present location at a time when the wave-action had become insufficient to carry them over the crest of the reef on to the beach on the lagoon side. Among the specimens along the beach on the lagoon side of the reef, by far the larger number were still attached to a piece of coral rock, usually one of small size. In almost every instance the skeleton shows that the colony was complete when washed on shore. Any physical injury undergone had not been to the extent of having branches broken off or, in the case of *G. flabellum,* having suffered any tearing of the blade of the leaf-like portion of the colony.

On the east side of Loggerhead Key, where the greatest force of the storm came across comparatively shallow water, it being approximately 3 miles from the reef mentioned in the previous paragraph, most of the specimens when examined in January 1911 had the spicule-bearing tissues present, although considerably macerated in many instances. None of these colonies showed any considerable amount of injury, such as the loss of branches or the tearing of the living tissues from the skeleton.

None of the common gorgonians of the Tortugas region can be kept alive for any considerable time after they have been broken off from their natural support and allowed to fall over into a horizontal position. When such a colony is put into a live-car, where most of the other local marine invertebrates and practically all of the sedentary cœlenterates can be kept alive for an indefinite period, it will be only 2 or 3 days before maceration sets in.

It seems apparent, therefore, that the greatest destruction resulting from hurricanes comes from the tearing of the gorgonian colonies from their natural supports, rather than from any lacerations of the tissues of the colony.

On the reef where the regeneration experiments previously mentioned were being carried on, a considerable number of colonies were carried away during the storm. Of the remaining colonies many were found in January 1911 which had suffered lacerations of noticeable extent. The most common injury observed was a destruction of the living tissues of the colony, such as would result from twisting such a specimen in one's hands while holding it firmly by each end. The loss of branches in the branched forms, or the tearing of the skeleton of the leaf-like portion of *G. flabellum,* was of very unusual occurrence. The injuries caused by the twisting from the waves were quite evenly distributed among the several species occurring on this reef. Such injuries often involved as much as half of the total surface area of the colony. In all large colonies of whatever species the injury was greatest over the basal portion, while the outer ends or branches were usually uninjured. At the time of the examination in January 1911 there had been comparatively little ingrowth of new tissue over the denuded areas, so that the extent of the injury to any colony could be readily determined. When the same specimens were examined in July 1911, in at least 50 per cent* of the specimens noted as injured at the time of the earlier observation, the reparation had been so complete that there was no longer any evidence of injury.

In all of the colonies where the injury consisted in the removal of the living tissues from about the base of the skeleton there was yet an area where the skeleton was exposed. In all cases where the injury was of this nature there was no evidence of any growth of the living tissues down over the naked skeleton. The exposed skeleton was usually covered with a dense growth of algæ, bryozoans, or hydroids, so that there seems to be no probability that it will be again covered with the usual tissues. The specimens of *G. acerosa* known to have been injured during the storm showed the same overgrowth of the denuded skeleton by the cœnenchyma, on which the polyps later made their appearance, as did those colonies from which the living tissues were removed in the regeneration experiments.

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* The examination in January 1911, was so hasty and incomplete that no reliable estimate of the number showing injuries could be made.

EMBRYOLOGY OF PALYTHOA.

Attempts to obtain the embryos of *Palythoa mammilosa* were continued during the present summer without success. The eggs were still immature when examined on August 7, although the testes were rapidly increasing in size and ripe active spermatozoa could be obtained in abundance. All attempts to induce artificial parthenogenesis resulted only in membrane formation without any subsequent segmentation.

EMBRYOLOGY OF FISSURELLA.

Two lots of *Fissurella* eggs were fertilized and carried through to the formation of free-swimming embryos. Some 50 individuals were collected on July 23, when the low spring tide came on an excessively hot day. None of the eggs from any of these specimens could be fertilized, and all subsequent attempts to fertilize the eggs of this form failed. As the result of the high temperature on the reef on the above-mentioned date more than 50 per cent of the snails collected at that time died, or were washed out from the shells (they may have been dead when taken into the live-car), during the succeeding night. As the ovaries of the females were full of eggs, which shook out when the ovary was put into a dish of water, it seems that the heat, which was fully 38° C., was sufficient to destroy the eggs without being great enough to kill all the snails.

The Madreporaria and Marine Bottom Deposits of Southern Florida, by Thomas Wayland Vaughan, U. S. Geological Survey.

During June 1911 studies of the life-history, growth-rate, and general ecology of the corals of southern Florida were prosecuted along lines begun in preceding years. Especial attention was paid to rearing coral colonies from planulæ that attached themselves in the aquarium and were therefore of definitely known age; to rearing colonies from planulæ that had settled on collectors and were therefore of ages approximately known; to planting in selected localities colonies cemented to terra-cotta disks (tiles); to making measurements of colonies growing naturally in certain localities; and to repeating annual surveys of the piers of the Fort Jefferson wharf and of the Fort Jefferson moat. One result of these experiments and observations was to obtain data on the factors that influence the attachment of planulæ, their survival after attachment, and their growth-rate should they survive. Other additional information on the general ecology of these organisms was procured, and new observations and experiments were initiated. A brief account of the investigations on the Madreporaria and a summary of the results obtained follow.

The effects of the hurricane of October 17, 1910, were studied, and a series of samples of the bottom deposits was collected on the Quicksands lying west of the Marquesas Keys and around the Marquesas. The information obtained from these sources will later be used in describing the active geologic processes of southern Florida. However, it may here be stated that there is much fine calcareous sediment on the Quicksands, and a deposit of ooze, of an undetermined number of feet in thickness, occurs in Marquesas Lagoon; this ooze is extremely fine and is probably a chemical precipitate. (For a possible explanation of such a precipitate, see the report of Mr. G. H. Drew, pp. 136–141 of this Year Book.)

RESULTS OF PLANULA CULTURES MADE IN 1910.

In 1910, 203 planulæ attached themselves, in culture-jars, to 21 terra-cotta disks (tiles). Of these 21 tiles, 13, bearing a total of 160 polyps, were placed in a floating live-car moored off the northwest face of Loggerhead Key; while 8, bearing a total of 43 polyps, were planted on stakes driven into the sea-bottom off the northwest face of the Fort Jefferson moat-wall. In order to identify colonies that might develop from the planulæ settled in the aquarium from colonies that might develop from adventitious planulæ after the tiles were planted in the ocean, a diagram was carefully made of each tile, showing the precise position of each attached planula. The necessity of this foresight was amply demonstrated. By 1911 at least 28 colonies, representing 3 species, had developed from the cultures of 1910.

PLANULA CULTURES PLACED IN THE FLOATING LIVE-CAR.

An account of the initiation of this experiment with its history to November 1910 is given in last year's report.[*] It is stated in a footnote that this car was sunk just before the hurricane of October 17, 1910, and that it was subsequently refloated. John Mills, the head mechanic of the laboratory, furnished notes on the condition of the cultures after the car was refloated, but they could not be included in last year's report. The following table presents the results of this experiment:

Record of tiles placed in live-car anchored off Loggerhead Key.

Culture number and name of parent.	No. of planulæ attached in May and June 1910.	Report of John Mills, Nov. 15, 1910.	Report of Dr. Mayer, Jan. 10, 1911.	No. of colonies June 1911.	No. of planulæ represented by colonies.
1. Favia fragum I[*]..	5	4 specimens; diam 4.7 mm.	3 specimens; diam. largest 9.5 mm.; intermediate 9 mm.; smallest 8 mm.	4	4
4. Porites clavaria I.	20	....	....	1	20
6. Favia fragum I...	2	....	....	1	1
8. Favia fragum III.	9	4 specimens; 2 diam. 4.7 mm.; 2 diam. 6.25 mm.	3 specimens; diam. largest 7 mm.; intermediate 6 mm.; smallest 5 mm.	4	9
22. Porites astreoides I.	2	1 specimen; diam. 3 mm.	....	0	......
24. Porites astreoides II.	28	7 specimens; 5 diam. 3 mm.; 2 diam. 4.7 mm.	....	7	12
25. Porites astreoides II.	70	12 specimens; 7 diam. 3 mm.; 3 diam. 4.7. mm; 2 diam. 6 mm.	....	0	......
39. Porites astreoides II.	8	4 specimens; diam. 3 mm.	....	0	......
				17	46

[*] The Roman numerals refer to the parent specimen. Cultures Nos. 8 and 24 are illustrated by plate 4, figs. 1 and 2.

The measurements of John Mills were expressed in fractions of an inch and were computed to millimeters. Some colonies escaped the notice of both Mills and Dr. Mayer, because of trying to make observations under water without removing the tiles from their places of attachment, the small size of the colonies, or concealment by sea-weed or other organisms. I removed the tiles from the car and cleaned and examined them in shallow vessels filled with water. In some instances the present colonies were probably formed by the fusion of several planulæ, or by the fusion of colonies developed from several planulæ. A consideration of the location of the tiles in the live-car shows that each of the three tiles in the anterior row of the five cross-rows bore one or more colonies; one tile in the second row, the one on the left side, bore 4 colonies; and one tile, the one on the right side, in the third row, bore 7 colonies. All colonies in the fourth row died. In the fifth row the polyps attached in one culture died; the specimens of *Agaricia* and *Favia* cemented to a tile all died, though it is known that the environment of the live-car is favorable for *Favia*. The bases of two specimens of *Porites astreoides* cemented to a tile were half dead in January, according to Dr. Mayer, but subsequently regenerated and grew rapidly. The sinking of the live-car probably brought about the death of the colonies near its rear end and on the left side forward beyond the middle.

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[*] Carnegie Institution of Washington, Year Book No. 9, 1910, pp. 142, 143, plate 4, figs. C and D.

When I examined the car in June of this year it was overgrown, inside and outside, by seaweeds of several species; there were also sponges, several species of mollusks, *Ostrea* and *Avicula*, and stalked barnacles, *Lepas*. The surfaces of the tiles were largely covered by these organisms, which often concealed the young corals and probably would ultimately have smothered them. Two water-buckets full of these overspreading organisms were removed from the car and specimens were preserved for future identification. This experiment has clearly proved that one factor determining the success of competing organisms is growth-rate. In locations where corals might grow rapidly they are smothered by other organisms that have a more rapid growth-rate. This subject will be subsequently reverted to in discussing other experiments and observations.

The following table gives the measurements of the colonies that survived in the live-car experiment:

Dimensions of corals surviving, June 1911, from planula cultures placed in floating live-car in June 1910, the colonies being one year old in June 1911.

Culture.	Specimen.	Parent.	Greater diameter.	Lesser diameter.	Height.	No. of calices.
			mm.	*mm.*	*mm.*	
1	*b*	Favia fragum I	13	12	4	9
1	*c*	.......Do..................	19	18.5	6	15
1	*d*	.......Do..................	20	18.5	5	17
1	*e*	.......Do..................	20.5	17.5	4.5	18
4	......	Porites clavaria I	7	6.5	......	......
6	......	Favia fragum I...........	5.5	5	......	*1
† 8	*a*	Favia fragum III	17.5	15	5	11
8	*b*	.......Do..................	13.5	12.5	3	4
8	*c*	.......Do..................	9.5	8	2.5	4
8	*e*	.......Do..................	8	7.5	2.5	3
‡ 24	*a*	Porites astreoides II.....	9	9	2 to 3	......
24	*b*	.......Do..................	23	14.5	3	......
24	*c*	.......Do..................	11	10	ca. 2	......
24	*d*	.......Do..................	5	4	ca. 2	......
24	*e*	.......Do..................	6	5	ca. 2	......
24	*f*	.......Do..................	4	3	ca. 2	......
24	*g*	.......Do..................	6.5	5	ca. 2	......

* Fission in process. † See plate 4, fig. 1. ‡ See plate 4, fig. 2.

In three instances—cultures 1, 8, and 24—there were adventitious specimens, in each case *Favia fragum*. An inspection of the table shows a great range in the size of colonies 1 year old. This variation may be largely explained by whether or no the young colony was more or less smothered by algæ or other overspreading organisms. The tiles in cultures 4, 6, and much of 24 were overgrown with sea-weed. Specimen *b* of culture 24 was probably formed by the fusion of colonies from 6 planulæ, attached on the periphery of the tile and not so shadowed or overgrown as the other colonies.

PLANULA CULTURES PLANTED ON STAKES OFF FORT JEFFERSON MOAT-WALL.

Eight tiles bearing polyps of *Porites astreoides,* derived from planulæ that attached in the aquarium, were planted off the northwest face of the Fort Jefferson moat-wall. The following table gives the record of these experiments:

Record of culture tiles planted off Fort Jefferson moat-wall.

Culture No.	Name of parent.	No. of planulæ attached in 1910.	No. of colonies surviving in 1911 at the end of one year.	No. of planulæ represented by colonies.
13	P. astreoides I........	5	1	1
14	P. astreoides II.......	6	0	0
30	P. astreoides I........	3	0	0
31	......Do...............	4	1	1
32	......Do...............	2	1	1
33	P. astreoides II.......	9	4	6
34	......Do...............	6	1	1
38	P. astreoides I........	8	3	4
		43	11	14

In 1910 attention was called to the variation in frequency of attachment of planulæ of respectively different parents. This experiment indicates that, once attached, the planulæ of different parentage have about equal chances of surviving. Planting the tiles directly in the ocean gave proportionately better results than planting in a floating live-car. In the live-car 160 planulæ gave 17 colonies, representing 46 planulæ (about 20 on culture 4 were originally in a cluster), while on the stakes 43 planulæ produced 11 colonies, representing 14 planulæ. The death of many of the young corals in the live-car was probably due to its sinking and to the hurricane. The tiles on the stakes suffered some, but not greatly, from the hurricane; considerable silt and sand settled on the upper surfaces. The following table gives the dimensions of these colonies:

Dimensions of Porites astreoides colonies surviving from planula cultures planted on stakes, showing the growth attained at the end of the first year of their lives.

Culture No.	Specimen.	Greater diameter.	Lesser diameter.
		mm.	*mm.*
13	*c*	13.5	11
31	*a*	18	15
32	*a*	7.5	5
33	*a*	9	8
33	*b*	7	6
33	*c*	9	8
33	*d*	9	6.5
34	*a*	19	18
*38	*c*	12.5	9
38	*d*	16.5	15
38	*c*	12	11

* See plate 4, fig. 3.

Of the culture-tiles that bore colonies in 1911, Nos. 8 and 24 were planted on stakes driven into the reef off the northwest face of Loggerhead, while all of the others were planted on stakes off the northwest face of the Fort Jefferson moat-wall. These colonies constitute a definite basis for the study of the growth-rate of the species represented and of the influence of environment on variation. These experiments and observations are being supplemented in several ways, accounts of which follow.

COLONIES FROM PLANULÆ SETTLING ON COLLECTORS.

Sixty-one tiles were attached to stakes driven into the reefs off the northwest face of Loggerhead Key in 1909. The upper surfaces of these tiles were examined in June 1910 and June 1911, to discover any young colonies that might be growing on them, but none were found. The aggregate area of the upper surfaces of these tiles is about 24 square feet; as the tiles were out for 2 years, the exposed surface would be equivalent to 48 square feet for 1 year, or a square about 7 feet on each side, assuming conditions in the two years to have been similar. These tiles were planted among corals, at depths below the water-level of the lowest observed tides. This experiment clearly shows that smooth, flat, horizontal surfaces *on reefs* are not favorable locations for the attachment of coral larvæ. It was observed that adventitious planulæ had attached to the upper surfaces of the tiles in the floating live-car and to the upper surfaces of some of the tiles on stakes off the northwest face of the Fort Jefferson moat-wall. The conclusion from these observations seems substantiated, that the strong forward and backward flow of water over reefs, with the flood and ebb of the tides, together with the exposure to storms and the consequent breakers, prevents planulæ from settling on smooth, open, horizontal surfaces, while they will settle on such surfaces in more protected situations.

The tiles planted on stakes off the northwest face of the Fort Jefferson moat-wall bore numerous young colonies, less than one year old, on their peripheries and under surfaces, as well as on their upper surfaces. This observation led to the inspection of the peripheries and under surfaces of 19 tiles planted as collectors on Loggerhead Reef. Nine of these tiles bore a total of 18 young colonies. These observations indicate that on the reefs planulæ effectively attach themselves in the more protected places. An examination of the natural surfaces of the Loggerhead reefs to find young colonies revealed very few, some *Favia fragum* and some *Porites astreoides* growing in protected places. Although a more thorough inspection would doubtless have yielded a larger number, the important factors controlling effective attachment seem evident.

Many of the colonies developed from naturally attached planulæ were photographed and measured, and incorporated in the series of studies in growth-rate. Tile 15 is illustrated by plate 4, fig. 4. The table on page 152 presents the dimensions of these yearlings:

Culture-tiles 13, 14, and 30, and tile 15, were inverted because of the large number of colonies growing on the under surfaces, while there were no living colonies on the upper surfaces. The following colonies were on the peripheries of these tiles:

Culture 13, *c* (*Porites astreoides* from planula culture), *g* (*Porites astreoides*).
Culture 14, *a*, *d* (*Favia fragum*), *i* (*Porites clavaria*).
Culture 30, *b* (*Favia fragum*), *c* (*Porites astreoides*), *f* (*Favia fragum*), *j* (*Porites astreoides*).

These data show the great preponderance of attachments in nature to be on the lower surfaces of the tiles. However, though the conditions are most favorable for original attachment and initial growth on the free under surfaces of objects immersed in the water, such a habitat is not the most favorable for the ultimate survival of the young corals. On the lower surfaces of the tiles algæ of various species, sponges, and Bryozoa, that have a more rapid growth-rate than the young corals, grow luxuriantly and frequently smother more slowly growing organisms. In the competition between attached and

Table of dimensions of naturally attached yearling corals.

Name of species and present location.	Greater diameter.	Lesser diameter.	Height.	No. of calices.
Eusmilia knorri:	*mm.*	*mm.*	*mm.*	
Fort Jefferson wharf, pier II, 15 *b*...	22	18	17 to 18	1
Fort Jefferson wharf, pier II, 15 *a**..	33	27	17 to 18	2
Favia fragum:				
Culture 1, *a*, off moat-wall........	12	10.5	4	9
Culture 8, *d*, Loggerhead Reef.....	10	9.5	ca. 2.5	7 or 8
Culture 13, *a*, off moat-wall........	10	8.5	....	....
Culture 13, *b*, off moat-wall........	13.5	13	....	....
Culture 13, *d*, off moat-wall........	18.5	17.5	....	....
Culture 13, *e*, off moat-wall........	11	11	....	....
Culture 13, *f*, off moat-wall........	10.5	9.5	....	....
Culture 14, *a*, off moat-wall........	9.5	9.5	....	....
Culture 14, *c*, off moat-wall........	9	8	....	....
Culture 14, *d*, off moat-wall........	11.5	9	.....	....
Culture 14, *e*, off moat-wall........	12.5	9	....	....
Culture 14, *f*, off moat-wall........	9	8	....	....
Culture 14, *g*, off moat-wall........	17.5	16	6	....
Culture 14, *h*, off moat-wall........	15	11	....	....
Culture 14, *j*, off moat-wall........	11.5	8.5	....	....
Culture 14, *k*, off moat-wall........	16	15.5	4	....
Culture 24, *h*, Loggerhead Reef.....	9.5	8	....	....
Culture 30, *a*, off moat-wall........	11.5	9	....	....
Culture 30, *b*, off moat-wall........	12.5	12.5	....	....
Culture 30, *e*, off moat-wall........	10	7	....	...
Culture 30, *f*, off moat-wall........	6.5	6.5	....	....
Culture 30, *h*, off moat-wall........	17	17	....	....
Culture 30, *i*, off moat-wall........	9.5	8.5	....	....
Culture 30, *l*, off moat-wall........	12.5	11.5	....	....
Culture 30, *m*, off moat-wall........	11	6	....	....
Culture 38, *a*, off moat-wall........	10	....	....	....
Tile 15, *b*, off moat-wall............	18	15	....	....
Tile 15, *d*, off moat-wall............	12	12	....	....
Tile 15, *e*, off moat-wall............	17	17	....	....
Tile 15, *f*, off moat-wall............	12	10	....	....
Agaricia fragilis var.:				
Culture 30, *d* (died)...............	10	7	....	....
Culture 30, *g* (died)...............	15	15	....	....
Tile 15, *a* (died)..................	14	10	....	....
Porites clavaria:				
Culture 14, *b*, off moat-wall........	9	9	....	....
Culture 14, *i*, off moat-wall........	11	10.5	....	....
Culture 30, *k*, off moat-wall........	11	10	....	....
Culture 34, *b*, off moat-wall........	6.5	5.5	....	....
Culture 34, off moat-wall (lower surface)......................	11	8	....	....
Tile 15, *c*, off moat-wall............	16	15	....	....
Porites astreoides:				
Culture 13, *g*, off moat-wall........	13.5	10	....	....
Culture 30, *c*, off moat-wall........	17	15.5	....	....
Culture 30, *j*, off moat-wall........	12	9	....	....
Culture 31, *b*, off moat-wall........	13	8.5	....	....
Culture 38, *b*, off moat-wall........	4.5	4.5	....	....

* Perhaps 2 years old.

incrusting organisms, growth-rate is one of the most important factors in determining which shall survive. Corals may grow with great rapidity in locations where they can not survive, or are only poorly represented, because the habitat is suited to other organisms of a more rapid rate of growth. In the vicinity of the Tortugas there are many obstacles in the way of free planulæ obtaining a footing and developing into colonies. They settle and begin their initial development best precisely in those places where they are most likely to be smothered by other organisms. The relatively small number of planulæ that attach in crevices or small protected spots, in which seaweeds, sponges, etc., do not get a footing, and when the environment is unfavorable for the growth of these, are those that have the best opportunity for growth and ultimate survival. To offer a proper foundation for a coral reef, the sea-bottom must, besides being hard, clean, with a free circulation of water over it, also be rough. Irregularities in the surface constitute an essential factor.

A comparison of the table of dimensions of the colonies naturally attached to tiles shows that the largest colonies of *Favia fragum* and *Porites astreoides* derived from planulæ that settled in the aquarium exceed in size the largest colonies from planulæ that settled under natural conditions. The relatively smaller size of the latter may confidently be explained by their being somewhat younger. But the average difference in size between the culture colonies and the natural colonies is not great. Rearing colonies obtained in this way furnishes directly positive data on the growth-rate of the species represented, and also furnishes a reliable basis for estimating the approximate age of other colonies discovered in nature.

PLANTING CORALS CEMENTED TO TILES

A total of 96 specimens of corals in 1910 were cemented to 24 tiles, 22 of which, bearing 86 specimens, were planted on stakes off the northwest face of the Fort Jefferson moat-wall; while 2, bearing 10 specimens, were placed in the floating live-car moored off the northwest face of Loggerhead Key. When examined in June 1911 it was found that 8 specimens had been broken off the tiles and that 12 had died, 3 more dying between the time of removing the tiles from the stakes for measuring and photographing and that of replacing them on the stakes. Seven of the dead corals were on one tile in the floating live-car (4 *Agaricia crassa* and 3 *Favia fragum*). It seems very doubtful from other experiments that the *Agaricia* will survive in water so shallow, directly exposed to the rays of the sun, as this coral apparently needs a more attenuated light; but the *Favia* was doubtless killed by the sinking of the car. The other specimens that died before June 14, 1911, were 4 *Astrangia solitaria* and 1 *Agaricia crassa;* the 3 that died between taking up and replanting the tiles were 2 *Agaricia fragilis* var. and 1 *Siderastrea radians.* These experiments give an idea of factors influencing the life of these corals and their relative hardiness. *Astrangia solitaria* is usually found on the reefs attached to the under side of stones, etc. It probably could not stand the exposure to strong sunlight in which it was placed when planted on the upper surface of the tile. Other experiments showed that placing corals accustomed to attenuated light in strong sunlight, in very shallow water, would either injure or kill them. *Agaricia* lives in more or less shaded places and appears to be a delicate coral. Why the specimen of *Siderastrea radians* died was not explained.

Of the 96 corals cemented to tiles in 1910, 73 remained for further observation. These 73 specimens furnish important information on the growth-rate and the vicissitudes of coral life, which is often a struggling life. There is, especially among the less rapidly growing corals, a constant struggle against overspreading organisms, which, though they may not kill the corals, at least greatly retard their growth. By using the yearling colonies a judgment may be formed of the approximate ages of young specimens; by seriating the specimens it is possible to estimate the age of larger specimens. The growth-rate is frequently rapid, bearing out the estimates published in Year Book No. 9, pp. 136–140. To present in detail the results of this series of experiments would require more space than it is desirable to take here; but 7 of the experiments are illustrated on plate 4, figs. 5, 6, and plates 5 and 6. (For explanation of plates see page 156.)

The result of one experiment with *Agaricia* gave unexpectedly important information on the influence of environment on variation. On the piers of the Fort Jefferson dock a thin, unifacial, subcircular, or reniform *Agaricia,* attached by the center of the lower surfaces, is rather abundant. This seems to be a variety of *Agaricia fragilis* (Dana). On the reefs off Loggerhead Key an *Agaricia* of massive form, several inches in diameter and of somewhat less height, is abundant. This appears to be the same as *Agaricia crassa* Verrill. One specimen of the thin *Agaricia fragilis* form attached to a tile in June 1910 had by June 1911 assumed the *Agaricia crassa* growth-form. This specimen was attached by its entire lower surface and seems to have had its growth-form influenced by the wide basal attachment. It is evident that there is here one species of *Agaricia* that under different conditions assumes different growth-forms. In very quiet water it is thin, orbicular, or reniform, with a slight basal attachment at its center, while on the reefs it is more strongly attached and has a more massive growth-form. But, in the quiet waters, the massive growth-form may be produced by giving the normally thin form a wide base of attachment, or there is a reaction to contact. On the reefs, when the water is strongly agitated, there is probably a clinging of the peripheral polyps to the basal support; this causes the basal attachment to cover a larger area than in the more quiet waters; then upward growth from this wide base would produce the massive form.

The number of specimens cemented to tiles was, in June 1911, increased by 37 specimens cemented to 26 tiles, 17 of which were planted on Loggerhead Reef and 9 off the northwest face of the Fort Jefferson moat-wall. Besides the measuring and photographing of the specimens, they were weighed before attachment to the tiles and the tiles were weighed with the specimens attached. Among these specimens were young *Eusmilia knorri* and young *Manicina gyrosa.*

RECORDS OF CORALS GROWING NATURALLY.

The records of growth of corals growing naturally and the survey of certain coral areas were repeated in 1911.

Fort Jefferson wharf.—The piers of the Fort Jefferson wharf, which have been annually surveyed in order to notice any changes that may take place in the corals attached to them, were again surveyed in 1911. In 1910 33 corals, growing attached to the piers of the wharf, were under observation for growth-rate, measurements having been made of most of them. Of these specimens, 3 had been broken off in 1911, and 8 specimens under observation were not observed again because of rough water at the time of inspection. Records were made of 22 of the 33 specimens in 1911; 4 of these were removed and cemented to tiles. The observations were increased by 6 new records. These records include several young specimens of *Eusmilia knorri* and *Manicina gyrosa.*

Fort Jefferson moat.—The annual surveys of this moat were again repeated. An account of the low tides of June 6–8, 1910, was published in Year Book No. 9, pp. 135–136. The opinion there given of the ability of corals to withstand atmospheric exposure was in general substantiated. Colonies of *Eusmilia, Orbicella,* and *Mœandra clivosa* were killed; specimens of *Mœandra clivosa, Mœandra viridis,* and *Manicina gyrosa* were partially killed, the portions saturated with water remaining alive and subsequently growing. The specimens of *Favia fragum* grew less rapidly than during the preceding year, their growth apparently having been retarded. The specimens of the three species of *Porites* showed no evidence of having been injured. Three specimens of *Siderastrea radians* died. As their loss may have been caused by exposure between tides, this species may be more susceptible to injury through atmospheric exposure than was supposed.

Although corals permanently submerged, but above the silty bottom, find favorable conditions for vigorous growth in the moat, there is a constant struggle for life between the corals and organisms that tend to overgrow them. The inimical organisms comprise algæ (among which *Halimeda* is prominent), sponges, tunicates, etc. A collection of these was made for purposes of specific identification. In this struggle the organism that grows the most rapidly is the victor.

In 1910, 38 colonies in the moat were measured for growth-rate; in 1911, 6 of these (1 *Eusmilia knorri,* 1 *Orbicella annularis,* 1 *Mœandra clivosa,* and 3 *Siderastrea radians*) were dead, 1 colony was overlooked, and 3 colonies of *Oculina diffusa* were in bad condition, having been almost smothered by *Halimeda* and the ascidian *Cione atra.* Growth-records on 31 colonies were continued.

Outer face of the northwest side of Fort Jefferson moat-wall.—Fifteen colonies growing attached to the outer face of the northwest side of the Fort Jefferson moat-wall were measured in 1910. In 1911, 8 of these were again measured; 7 colonies were lost in some way. Five of the lost colonies were *Favia fragum,* living near the base of a colony of *Porites furcata.* Several or all of these colonies were overgrown and smothered by the *Porites,* which has a much more rapid growth-rate.

Reefs off the northwest face of Loggerhead Key.—A reëxamination of the reefs off Loggerhead Key showed that the tops of the heads of *Orbicella annularis,* exposed during the low-tide period of June 6–8, 1910, had been killed, and that regeneration was taking place along the living edges below the dead areas.

Nineteen colonies growing on the reefs were measured in 1910; 18 of these were remeasured in 1911, one of the specimens of the previous year's records having been washed away by a storm. As a new record was added, the number of colonies being measured remain 19, as in 1910.

PLANULA CULTURES, 1911.

As so many young colonies of *Favia fragum* and *Porites astreoides* were obtained from the planula cultures of 1910, no attempts were made to obtain additional colonies of these species in 1911. Fifty cultures containing planulæ of *Agaricia* and *Porites clavaria* were installed, but they were not very successful, probably because of impure sea-water. A total of 28 planulæ of *Agaricia* attached themselves to 5 tiles, which were planted in water 2 or 3 feet deep at extreme low tide, off the northwest face of Fort Jefferson moat-wall. As Dr. Mayer has provided apparatus for pumping pure sea-water through a glass circuit, in the future there should be no trouble from contaminated water.

TEMPERATURE RECORDS.

An arrangement was made with Mr. George C. Short, of Fort Jefferson, to take temperature readings, twice daily, in three selected localities, for one year. The readings are to be made at 7 a. m. and 3 p. m., at the Fort Jefferson wharf, at the sally-port of the moat, and outside the moat-wall at the flood-gate. These records will furnish accurate information on the temperature condition in three localities being especially studied.

EXPLANATION OF PLATES.

The disks to which the specimens are attached are 8 inches in diameter and have been reduced in the figures to about 2.5 inches in diameter, making the specimens approximately 5/16ths natural size.

PLATE 4.

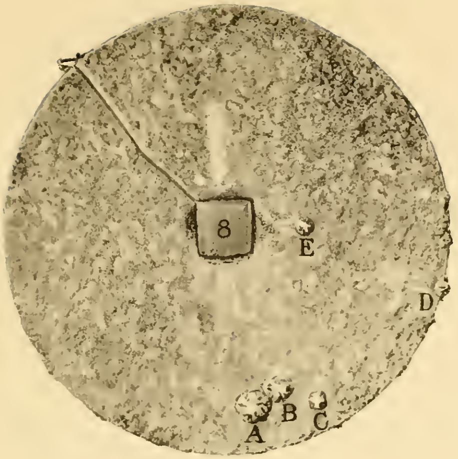
FIG. 1, Culture 8.—*Favia fragum: a, b, c, e,* from planulæ that attached in the aquarium between June 3 and 10, 1910; *d*, probably adventitious. Photographed June 19, 1911.
FIG. 2, Culture 24.—*a* to *g, Porites astreoides,* from planulæ that attached in the aquarium between May 29 and June 6, 1910; *h, Favia fragum,* adventitious. Photographed June 10, 1911.
FIG. 3, Culture 38.—*a, Favia fragum,* adventitious; *b, Porites astreoides,* probably adventitious; *c, d, e, Porites astreoides,* from planulæ that attached in the aquarium between June 1 and 8, 1910. Photographed June 19, 1911.
FIG. 4, Tile 15.—Corals attached naturally to the lower surface of a tile planted June 7, 1910. *a, Agaricia fragilis* var.; *c, Porites clavaria;* all others *Favia fragum.* Photographed June 14, 1911.
FIG. 5, Tile 1.—*Mæandra areolata.* Photographed June 6, 1910.
FIG. 6, Tile 1.—Photographed June 14, 1911.

PLATE 5.

FIG. 1, Tile 6.—*Mæandra areolata.* Photographed June 6, 1911.
FIG. 2, Tile 6.—Photographed June 14, 1911.
FIG. 3, Tile 2.—*Mæandra areolata.* Photographed June 6, 1910.
FIG. 4, Tile 2.—Photographed June 14, 1911.
FIG. 5, Tile 11.—*b, Porites astreoides; c, Porites furcata.* Photographed June 6, 1910.
FIG. 6, Tile 11.—Letters as in figure 5. Photographed June 14, 1911.
FIG. 7, Tile 14.—*Porites furcata.* Photographed June 6, 1910.
FIG. 8, Tile 14.—Photographed June 14, 1911.

PLATE 6.

FIG. 1, Tile 14*a*.—*a* and *b, Porites furcata; c, Porites astreoides.*. Photographed June 6, 1910.
FIG. 2, Tile 14*a*.—Letters as in figure 3. Photographed June 14, 1911.
FIG. 3, Tile 12.—*Porites clavaria.* Photographed June 6, 1910.
FIG. 4, Tile 12.—Photographed June 14, 1911.



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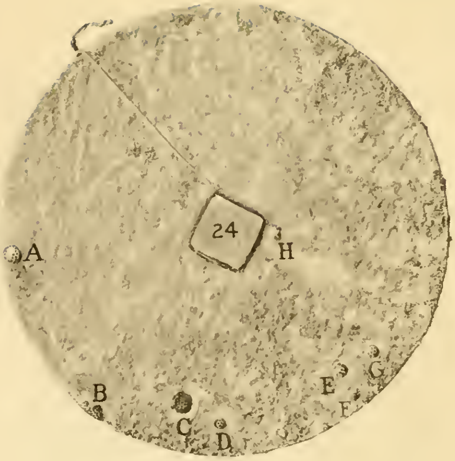
24
A
H
B
C
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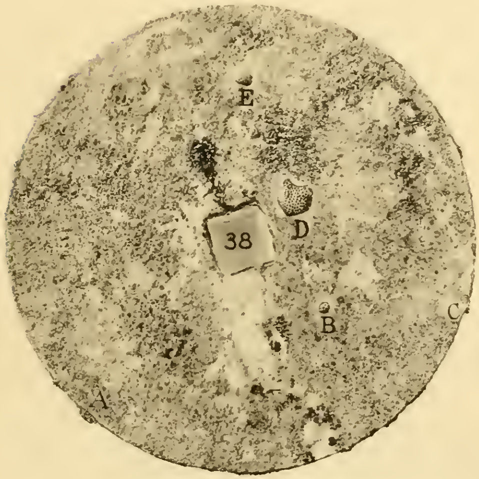
2



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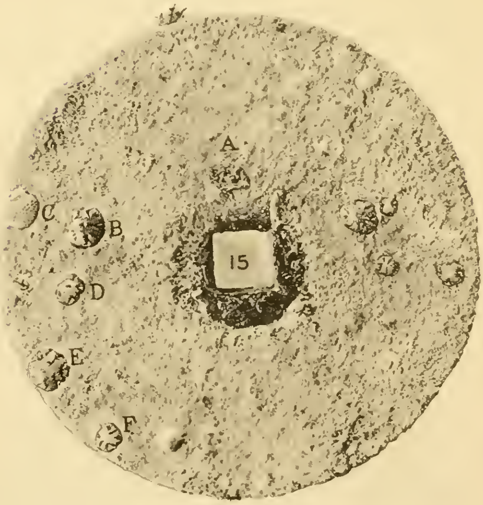

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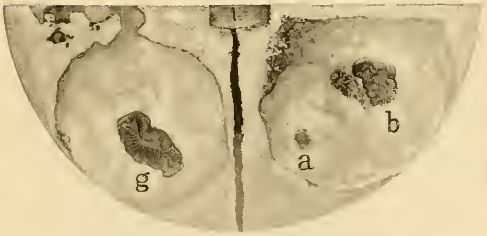

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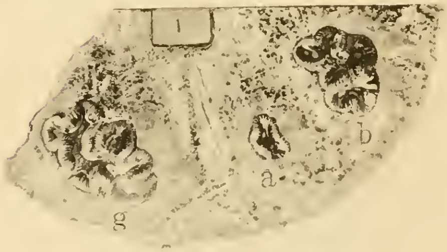

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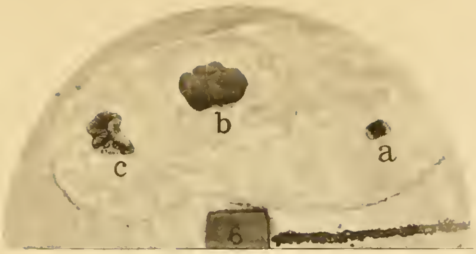
FIGS. 1 to 4 show year old Corals.
FIGS. 5 to 6 show one year's growth of Mæandra areolata.

PLATE 5



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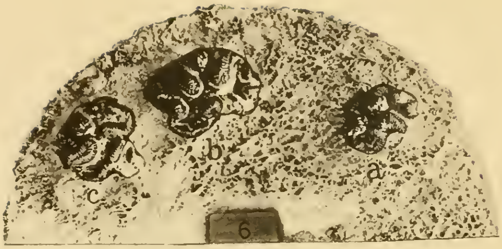

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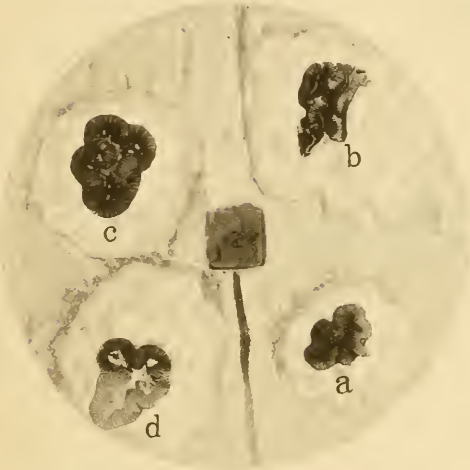

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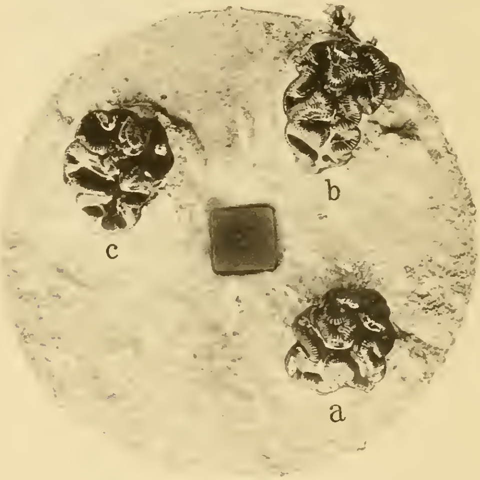

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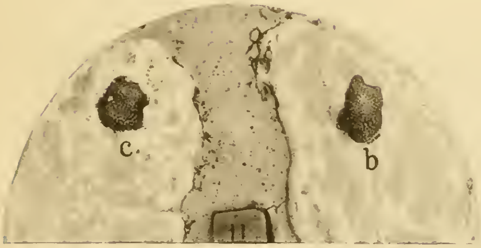

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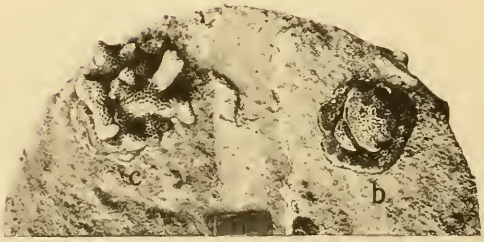

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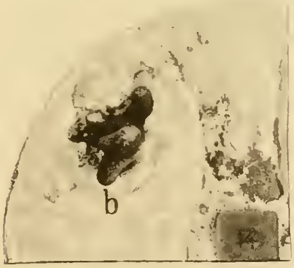

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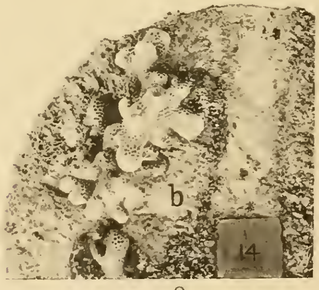

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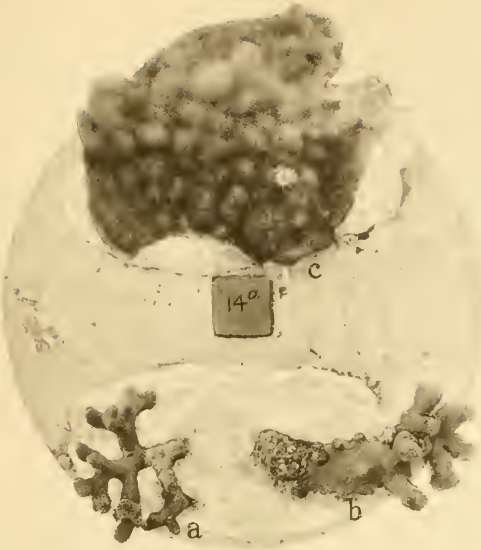
FIGS. 1 to 4 show one year's growth of Mæandra areolata.
FIGS. 5 to 8 show a year's growth of specimens of Porites.



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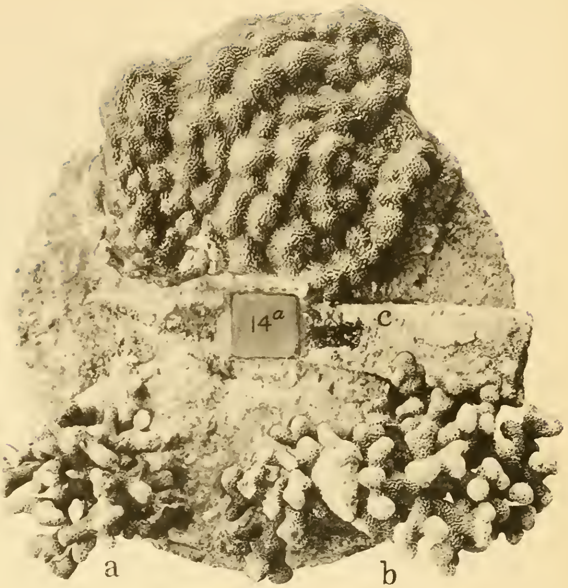

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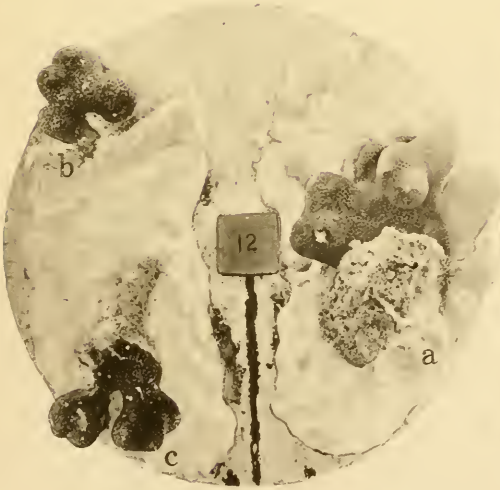

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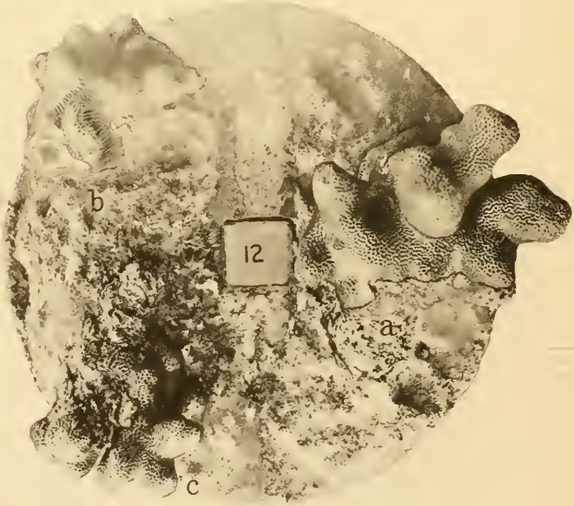

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FIGS. 1 to 4 show a year's growth of specimens of Porites.

DEPARTMENT OF MERIDIAN ASTROMETRY.*

Lewis Boss, Director.

This report covers the period from September 1910 to September 1911, during which the meridian observations undertaken at our southern station in San Luis, Argentina, were completed. At the close of observations in January 1911 about 87,000 complete observations in 654 series had been secured. The transit circle was promptly dismounted, carefully packed, and shipped to Albany, arriving in the latter part of April 1911, presumably without serious injury, though there has been no opportunity as yet for a definitive test by refined instrumental determinations. The entire staff arrived at Albany and reported for duty then or within the next two months. Prof. R. H. Tucker resigned to take effect July 1, in order to resume the position which he formerly occupied at the Lick Observatory. Mr. R. F. Sanford also resigned to take up work with the Mills Chilean Expedition, established by the Lick Observatory at Santiago de Chile.

It had been a part of the program for the expedition to San Luis to employ a photometer equipped with a photographic wedge. The latter was kindly provided by Professor Pickering. Differential observations of magnitude are planned for all stars of our meridian-circle program for which the magnitude had not been determined by the Harvard College Observatory either at Cambridge, Massachusetts, or at Arequipa, Peru. This had not been accomplished, as originally contemplated, at the time when the meridian-circle observations had been completed. The resignation of recorders and assistants had reduced the force to a point where these photometer-observations became impracticable, unless the meridian observations should be materially curtailed. It was accordingly arranged to return the photometer to Albany for the purpose of minor alterations and additions necessary to facilitate its use, and to give opportunity to the observers who are to use it to acquire the requisite familiarity with its peculiarities and in its manipulation. This plan was carried out, and accordingly the instrument was set up at the Dudley Observatory on a suitable pier housed in a small and convenient shed. The instrument was placed in charge of Mr. Meade L. Zimmer as principal observer, and Mr. William Hunt, of Harvard University, was engaged as recorder. These two practiced diligently for nearly two months. They sailed for Buenos Aires July 20, 1911, taking with them the photometer, with subsidiary apparatus. It is proposed to make the measures of brightness purely differential, on the basis of the Harvard photometry as the standard.

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* Address Dudley Observatory, Albany, N. Y. Grant No. 680. $33,734 for investigations and maintenance during 1911. (For previous reports see Year Books Nos. 2–9.)

The principal interest in the computing section of the Department at the Dudley Observatory during the past year has been in the study of systematic proper-motion, based upon our Preliminary Catalogue of 6,188 stars, published early in 1910. It was for purposes similar to this that the researches upon proper-motion were originally undertaken by the Department of Meridian Astrometry.

This year has been fruitful in results. In a paper published in the Astronomical Journal, Nos. 623–624, April 3, 1911, it was found that when the stars are divided into spectral types the mean motions of successive types ascertained by their "cross-motions"—those at right angles to the meridians of solar-motion and to the line of vision—with their ascertained relations to the entire amount of motion in space, and assuming the velocity of the sun in space to be 20 k. per second (in his later paper Professor Campbell finds this velocity to be 19.5 k. per second), the mean half velocity of each type, arranging in the supposed order of age, beginning with the supposedly youngest, *B*, is as exhibited in the following table, in the last column of which are quoted the corresponding half velocities ascertained from the motions in the line of sight (radial velocities) determined at the Lick Observatory, or at the D. O. Mills station, near Santiago de Chile, upon stars of the fifth magnitude or brighter. The results for types *B* and *A* found by Frost agree with the corresponding values by Campbell.

Table of mean half velocities of stars of various spectral types as ascertained from a study of "cross motions" and of "radial motions."

Type.	Relative mean secular parallax.	Half velocity,* cross-motions.	Half velocity,† radial-motions.
	"	*km.*	*km.*
B	2.7	6.3	6.2
A	4.1	10.2	10.5
F	5.0	16.2	14.4
G	3.1	18.6	15.9
K	4.0	15.1	16.8
M	3.3	17.1	17.1

* Boss in Astronomical Journal, No. 624, p. 198.
† Campbell in Lick Observatory Bulletin, No. 196.

The accordance of the values of the mean half velocities of the proper-motions of the stars of the several stellar types most certainly indicates that there is a real acceleration with age if, as is commonly supposed, the types are correctly arranged in the order of age—*B* the youngest and *M* the oldest—considering only the stars of the foregoing list.

At the same time, with the researches in regard to the type already published and summarized in the preceding table, the general law of the velocities as to direction and of the relative velocity as to direction was carefully investigated. The conclusion can be summarily stated as follows: The distribution in direction seems to be virtually at random, but the linear velocities in the general direction of the constellation *Orion* (at approximately the right-ascension 90° in the Milky Way) and in the opposite direction have a greater velocity than those at right angles to this direction in the approximate ratio of 7 to 4. This result explains and makes more definite the phenomenon indicated in the researches by Kapteyn some years ago, on the basis of which he propounded the hypothesis that the universe of stars consists essentially of two intermingled streams moving in opposite directions, each containing substantially like mixtures of stars of the various types. Our researches brought out the fact that stars of the *B* type seem to have no special tendency toward larger mean motions in the preferential directions already indicated in the foregoing. This second branch of our recent researches, owing to unavoidable delays, has not yet been published, but the details have been prepared in full and have been preserved on our records since May 1911. From these it seems as if the preference of the larger motions for a given direction does not exist for the younger type of stars, *B*, but that it has gradually been impressed upon the stars with increasing age.

I have advanced the hypothesis that the acceleration of the motions, acting in a manner which seems to be selective on the basis of the physical condition of the stars, may have been due to repulsive rather than gravitational forces, and that the preference for a given direction may have been due to a kind of polarity in the action of these forces making them stronger in the given direction to which there is a tendency of the larger motions. It must be admitted that this explanation is speculative, but something like this is apparently rendered necessary by the phenomena which have been already demonstrated as having an existence, and they seem to be reasonable from the analogy of repulsive action upon the tails of comets.

In working out these results, my assistants, H. Raymond and Benjamin Boss, have taken a part that justifies their admission, in some measure, as joint authors, to whatever of credit attaches to results so important.

The work has suggested extension of these researches in various directions, and strongly indicated the advantages which are likely to result from a large accession of results for proper-motion, such as the projected works of the Department of Meridian Astrometry are likely to supply. But a great increase in the measurements of radial velocities is likewise demanded, and a further extension of the classification of spectral types covering stars of the seventh and even some stars of fainter magnitudes is almost equally indispensable for a full elucidation of the peculiarities of systematic motion already indicated.

The return of the staff of San Luis was preceded by the dispatch to Albany of the instrumental record of the meridian-observations, of which there were 87,000 in round numbers. This has afforded the opportunity to begin the systematic reduction of the observations. The constants for reduction in right-ascension except azimuth are completed and tabulated throughout from April 1909 to January 1911. Much progress has been made in their application to transits of standard stars.

The computation in duplicate of reductions from apparent to mean places has progressed well, having been completed for 485 out of the 654 series at this date (September 1).

The computation in duplicate of refraction has been finished for the entire program.

The magnitude-equation for each of the five observers of transits has been well determined. For four of the five observers these equations materially differ for transits north and south of the zenith respectively. The following summary exhibits the gist of these determinations and shows for the respective observers the effect upon the chronographic registry of transit due to a diminution of the brightness of star by one magnitude. That is to say, in the case of each observer the transit of a relatively faint star is retarded for the respective observers at the rate per magnitude shown in the table, and its registered transit requires a negative correction.

Summary of magnitude-equations.

Observer.	Relation of star to zenith.	
	North.	South.
	s	s
R. H. Tucker	*—.0150	—.0096
A. J. Roy	—.0151	—.0029
W. B. Varnum	—.0099	—.0026
M. L. Zimmer	—.0112	—.0083
R. F. Sanford	—.0051	—.0104

* The equation for R. H. Tucker for transits north of the zenith is expressed by a curve in which the difference at magnitude, $2\overset{\mathrm{M}}{.}0$, is $-\overset{s}{.}009$, and at $8\overset{\mathrm{M}}{.}0$ is $-\overset{s}{.}023$. The tabular value, $-\overset{s}{.}0150$, is the mean from fourth to eighth magnitude, corresponding to telescopic aperture of 4 inches. When aperture is 8 inches this rate corresponds to magnitude, $9\overset{\mathrm{M}}{.}5$.

Except for very faint stars, it is seldom necessary to employ an actual correction of more than two to three times that due to a diminution of one magnitude. Normally, the aperture of the object-glass of the telescope is reduced to 4 inches. Ordinarily stars brighter than $3\overset{\mathrm{M}}{.}5$ are seen through a wire screen that absorbs $3\overset{\mathrm{M}}{.}8$ (Harvard Scale). In order to produce a finer division of grades in diminution of the apparent magnitude of the focal image during transit, the screen for very bright stars was applied during the entire transit for the brightest stars; for two-thirds of the transit, for one-half the transit, or for one-third the transit, the screen was applied for successive diminishing grades of brightness. An arrangement was provided by which the 4-inch diaphragm could be removed and the stars observed through the full aperture of the telescope. This method was adopted in case of stars fainter than $7\overset{\mathrm{M}}{.}0$; and by this means the apparent brightness of these fainter stars was virtually increased by $1\overset{\mathrm{M}}{.}5$ over what they would seem to have if the 4-inch diaphragm had been used. Thus the entire range of magnitude over which the equations would be applicable would be diminished in extreme cases by over 5 magnitudes and the mean of the magnitudes which, on a given night, would serve as the arguments for taking out the correction, for the equation would ordinarily approximate to the fifth or sixth magnitude, with variations from this of the individual arguments ordinarily of less than 3 or 4 magnitudes.

Similarly the relative effect upon the time of transit was determined near the zenith, depending upon whether the observer registers a transit as for a north or as for a south star. The quantities exhibited in the following summary show the amounts that are to be applied to a transit south of the zenith to make it homogeneous for the respective observers with their transits of stars north of the zenith. The quantities are small, but in nearly every instance are material.

Transits of stars north minus south.

Observer.	N.–S. s
R. H. Tucker	—.011
A. J. Roy	—.036
W. B. Varnum	—.046
M. L. Zimmer	—.029
R. F. Sanford	—.018

The care exercised in determining this quantity for each observer should go far to compensate for any disadvantage that might be thought to arise from the non-adoption of a reversing-prism.

For polar stars of very high declination it was necessary to employ the eye-and-ear method for transits, and in determining the polar deviation it has been decided to employ that method as standard in taking the transits. For all the observers except one the systematic difference between transits obtained by that method from those obtained by chronographic registry was carefully determined, so that the results by the two methods could be rendered homogeneous.

As will be seen from my report for 1910 (p. 154), about 400 transits by reflection have been secured as a check upon systematic peculiarities in the instrumental results, both in right-ascension and zenith-distance. The comparison between direct and reflected observations has not yet been made.

It will be seen that the meridian-circle observations at San Luis were completed much sooner than our early predictions (or estimates of possible progress) would have led any one to anticipate. This remarkable result, so contrary to ordinary experience, implies at the height of the work a yearly rate of about 60,000 complete observations. This rate is fully four times that usually attained for observations of this class, even in series where the work has been prosecuted with considerable vigor. There are several explanations for this.

In the first place, there was an extraordinary number of clear nights, about 280 annually, or practically three times as many as are usually experienced at any given observatory on the Atlantic seaboard of the United States.

Secondly, the staff gave its entire energy to the work of observation without attempting much in the subsequent reductions, and this energy was manifestly very great and well organized. The result was that on the majority of clear nights the instrument was in use by two or three observers at each tour of duty (4 to 6 hours) from sunset to sunrise—one observer at the telescope and another at the microscope, four of which were read at each observation.

The staff at San Luis labored with extraordinary zeal and determination, as must be evident to any one acquainted with the details of such work. Each man seemed strongly to feel his individual responsibility, especially as they had decided to accomplish within two years a work originally estimated as likely to cover four years, supposing it to be carried on at high pressure. It scarcely need be stated that the health of several members of the staff, at various times, and especially near the end, became seriously impaired.

On the eve of the departure of Professor Tucker from San Luis prominent residents of that place gave a banquet in his honor and presented him with a gold medal commemorative of the observatory and its work, together with an address engrossed and signed, congratulating him upon the success of his work.

At this date (September 15) considerable progress has been made in remounting the transit circle on its old piers at Albany. Messrs. Roy and Varnum have taken the most responsible part in this work. With their experience it has been possible to accomplish this remounting in a much more satisfactory and precise manner than on any former occasion when this work has been undertaken, either here or at San Luis. The instrumental tests will follow as soon as practicable, and it is proposed to resume the corresponding observations at Albany before next winter.

MOUNT WILSON SOLAR OBSERVATORY.*

Walter S. Adams, Acting Director.

The investigations completed during the past year have comprised numerous studies in solar spectroscopy, direct photography, and photometric and spectroscopic observations of stars and nebulæ with the 60-inch reflector, and a wide variety of laboratory researches. The year has seen the commencement of several extensive investigations, particularly in stellar spectroscopy and photometry, which will require several years for completion, but which should prove of high value in connection with certain of the problems of stellar distribution. The fact that the solar activity is still near its minimum, and that consequently very few sun-spots have appeared during the past year, necessarily has prevented any large amount of work upon the nature of the magnetic field in sun-spots. With increasing solar activity this work will be carried on with the aid of the 150-foot tower telescope.

Among the results of the investigations completed during the year we may refer to the following:

(1) The determination of the probable system of circulation of calcium vapor in sun-spots and the regions surrounding them.

(2) The fact that calcium vapor has a radial motion inward across the penumbræ of sun-spots. This is occasionally found combined with a rotary motion resulting in the formation of vortical structure similar to that found in $H\alpha$ flocculi photographed with the spectroheliograph.

(3) In addition to calcium vapor, which is always found flowing into sun-spots, a study of the lines of other elements indicates a motion generally inward on the part of hydrogen and frequently inward on the part of magnesium and sodium. This is true of the high-level or, in general, stronger lines of these elements. For the low-level lines the reverse is true, the motion being outward (the Evershed effect), and between the two are found lines which indicate essentially no motion. The relative level of the gases producing different spectrum lines may perhaps be determined in this way.

(4) Measurements upon spectra of the two opposite edges of the sun in three different regions of the spectrum have given values for the rotational velocity at the equator and at 15° of latitude which are slightly less than 1 per cent smaller than the values found in 1908. Between 30° of latitude and the pole the values are almost identical. It is doubtful whether this small difference represents a real variation in the sun's rate of rotation in these latitudes.

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* Situated on Mount Wilson, California. Grant No. 682. $106,055 for construction, investigations, and maintenance during 1911. (For previous reports see Year Books Nos. 3-9.)

(5) The continuation by two different methods of the study of the possibility of determining photometric magnitudes with the 60-inch reflector by the use of diaphragms over the mirror indicates that over a range of 5 magnitudes the effect of the change in the diffraction pattern produced by reducing the aperture is practically negligible.

(6) The same investigation shows, however, that the correction to the observed magnitudes depending on the distances of the stars from the center of the plate is very large and variable from plate to plate. The correction is dependent upon the size of the photographic star-image, but is independent of the color of the star and of the various factors entering into the development of the photographic plate.

(7) About 600 photographs of the spectra of nearly 200 stars between the fifth and seventh magnitude have been obtained since December with the 60-inch reflector, at the secondary focus of 80 feet. Of these, 50 are of the solar type of spectrum and the remainder are of types A and B. The spectra have been employed both for purposes of classification and for determinations of radial velocity. Over 50 spectroscopic binaries have been discovered during the measurement of the photographs.

(8) Photographs of the spectra of three globular star-clusters confirm the result found in 1910 from nine clusters, that these objects have in general a spectrum of the F type. One spiral nebula has been found giving a spectrum of the K type; all others that have been investigated show spectra of the G type.

(9) A continuation of the statistical study of the motions of stars of the *Orion* type of spectrum leads to a modification of the view that the *Perseus* and *Scorpius-Centaurus* groups represent two great star-streams among the *Orion* stars. It now appears probable that they form a part of a single stream to which all known *Orion* type stars must belong. The existence of the two-stream motion for stars of the solar type and type A, but not for the *Orion* type stars, may find an explanation in the hypothesis that the number of stars belonging to the second stream is a function of the spectral type, and decreases steadily from the solar type through type A to the *Orion* type.

(10) A study of the Zeeman effect for about 1,120 lines in the spark spectrum of iron and titanium has given the following results:

(*a*) The relationship of the measured separations to the normal interval agrees closely with Runge's law.

(*b*) Groups of lines of the same type of resolution are found among the more complex types for which the similarity of the intervals between the components indicates an intimate relationship.

(*c*) The law that the mean separation is proportional to the square of the wave-length is found to hold closely for the average of the lines taken in successive intervals throughout the wide range of wave-length covered by the observations.

(*d*) The enhanced lines show no distinctive behavior as regards type or magnitude of separation. The stronger enhanced lines of titanium are almost without exception triplets for which the separation is moderate and not related closely to the normal interval.

(*e*) No direct connection between magnetic separations and pressure displacements has been found. There is, however, a general agreement between the mean results for large numbers of lines.

(11) A comparative study of the Zeeman effect for 14 metals for which results are available has shown that in all cases the triplets are similarly distributed with respect to their separations in a standard magnetic field. From a combination of the measures for about 2,900 lines a value was found of the ratio e/m in excellent agreement with that determined by other methods.

(12) An investigation of the displacements of the spectrum lines in the arc and spark spectra of iron and titanium under pressures between 2 and 16 atmospheres has been carried on in the laboratory. The results indicate:

(*a*) That the displacements in the arc spectrum are directly proportional to pressure and amount, on the average, at λ 4500 to 0.0045 Ångström per atmosphere for iron and to 0.0042 Ångström for titanium.

(*b*) That the displacements in different parts of the spectrum are closely proportional to the third power of the wave-length in the case of iron, and to the second power of the wave-length in the case of titanium.

(*c*) That the enhanced lines present in the arc spectrum of titanium are displaced on the average considerably more than the majority of the other lines, and reverse much less readily under pressure.

(*d*) That in the same region of the iron-spectrum groups of lines may be selected having average displacements differing widely from one another, with which the displacements of groups in other parts of the spectrum are connected by the relationship of the cube of the wave-length.

(*e*) That there is no definite evidence of the existence of a relationship 1 : 2 : 4 between the displacements of the lines in the spectrum either of iron or titanium when all of the lines are included in the discussion, such as was suspected by Duffield from his investigation of the iron spectrum.

(13) An investigation of the effect of pressure upon the furnace spectra of iron, titanium, and vanadium indicates:

(*a*) That the displacements of the lines in the furnace spectra are consistently larger than those in the arc spectra under equal pressures, at least in certain regions of the spectrum, in some cases the differences amounting to 100 per cent. The difference does not depend on the nature of the compressed gas.

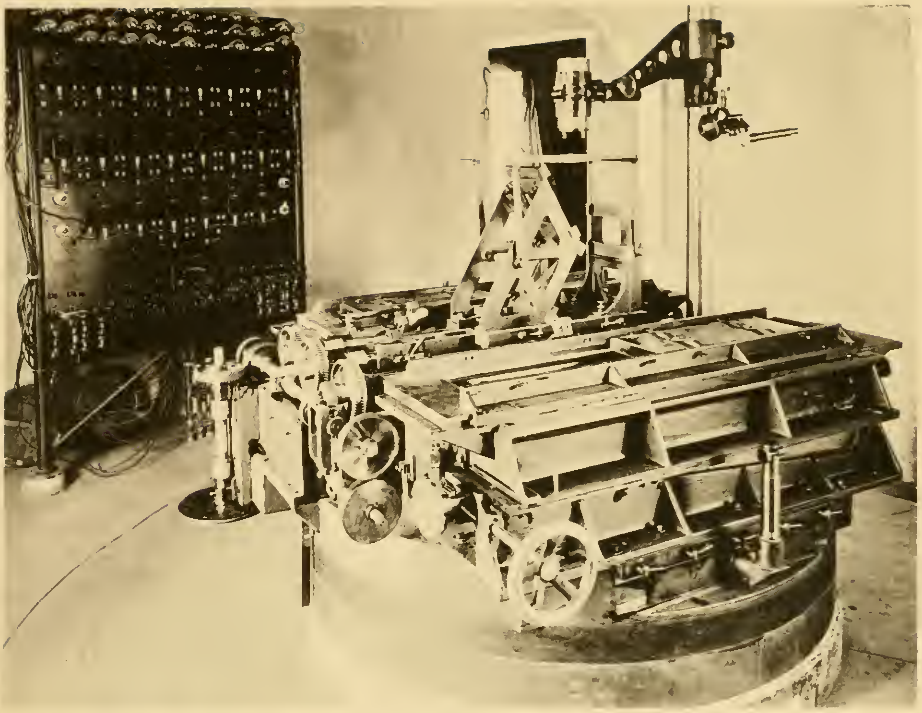
(*b*) The relative displacements of the furnace lines follow closely, in general, those of the arc lines.

(*c*) The displacements are closely proportional to pressure.

STAFF.

The staff of the Observatory has remained almost unchanged throughout the year. In the absence of Mr. Hale, Mr. Adams has served as acting Director, and has been engaged in stellar spectroscopic work with the 60-inch reflector. Mr. F. H. Seares has continued his photometric investigations on faint stars with the reflector, remaining in charge of the computing division and of the editorial work connected with the Observatory publications. Dr. Arthur S. King has continued to act as superintendent of the physical laboratory in Pasadena. Mr. G. W. Ritchey has resigned from the regular staff of the Observatory, but his services for a portion of his time have been retained for optical work upon the 100-inch mirror. Dr. C. E. St. John has carried on numerous solar spectroscopic investigations with the 60-foot tower telescope. Mr. Ferdinand Ellerman has continued in charge of the observations with the spectroheliographs of the Snow and tower telescopes. Mr. H. D. Babcock has devoted a part of his time to stellar spectroscopic work with the 60-inch reflector and the remainder to investigations in the laboratory in Pasadena. Dr. E. A. Fath has continued his spectroscopic studies upon the spectra of nebulæ and star-clusters and has made many photographs of the Kapteyn Selected Areas with and without color filters and absorption screens. Mr. F. G. Pease assisted during the winter in the stellar spectroscopic work with the 60-inch reflector and has commenced recently a series of direct photographs of nebulæ and star-clusters with the same instrument.

Prof. J. C. Kapteyn, of the University of Groningen, Research Associate of the Carnegie Institution of Washington, has, as usual, spent the months of July and August at Mount Wilson. A large part of his time has been devoted to a study of the problem of streams among stars having spectra of the *Orion* type, employing for this purpose the radial velocities obtained during the year with the 60-inch reflector. The close connection of these two lines of work should prove of the greatest value to each. Dr. Henry G. Gale, of the University of Chicago, Research Associate of the Carnegie Institution of Washington, spent the months of March, April, and May in Pasadena engaged in an investigation of the displacements under pressure of the spectrum lines of iron and titanium in the electric arc and spark. Dr. Arnold Kohlschütter, of the observatory at Hamburg, arrived at Mount Wilson in July and will spend the coming year at the Observatory as a volunteer assistant. He is at present engaged in the classification of the stellar spectra made with the 60-inch reflector.



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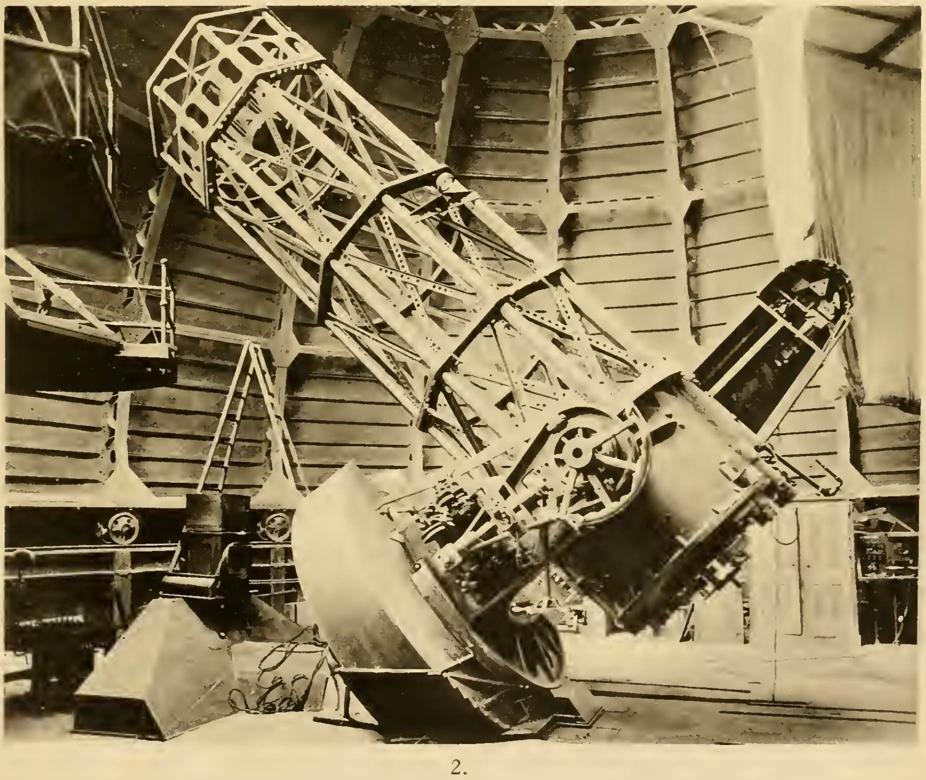

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Fig. 1. Upper end of 75-foot spectrograph in the 150-foot tower telescope.
Fig. 2. The Cassegrain spectrograph attached to the 60-inch reflector.

INVESTIGATIONS IN PROGRESS.

SOLAR RESEARCH.

Direct Photography of the Sun.

As in previous years, direct photographs of the sun have been taken on practically all clear days. The negatives are used in connection with studies of regions around sun-spots and are employed occasionally for the determination of the heliocentric coördinates of sun-spots. They serve also as a valuable record of the general state of the solar surface.

Work with the Spectroheliograph.

The general plan of work with the spectroheliograph during the year has been that outlined in the last annual report, although the very small number of sun-spots available for study has limited the number of photographs taken with the high-dispersion spectroheliograph of the 60-foot tower telescope.

During the year photographs have been made with the 5-foot spectroheliograph and the Snow telescope on 291 days, and 815 spectroheliograms of the solar disk with H_1, H_2, $H\alpha$, $H\beta$, and $H\delta$, and of the prominences with $H\alpha$, have been obtained.

When spots have been available photographs have been made with the 60-foot tower telescope and the 30-foot spectroheliograph. With this instrument, which is of the auto-collimating type, a prism of 63° of dense flint glass has been used for the work requiring the highest dispersion, while a 60° prism of light flint has been found preferable when less dispersion and more light are desired. The photographs with this instrument have been taken, for the most part, with the slit set upon different portions of the lines K, H, and $H\alpha$. A few photographs have been made with some of the more prominent sun-spot lines. Mr. Ellerman has also made a number of photographs of small regions of the sun's surface with the violet and red edges of the $H\alpha$ line simultaneously, in continuation of an attempt made two years ago to detect possible effects of anomalous dispersion in this way. No certain differences with the two sides of the line have as yet been discovered.

In addition to the photography of limited areas of the sun's surface, it has seemed desirable to obtain some results upon the entire disk with the high-dispersion spectroheliograph. For this purpose an image-forming lens of 18 feet focal length has been used, giving an image approximately 2 inches in diameter.

The study of the areas, distribution, and intensity of the calcium flocculi upon the H_2 photographs has been continued regularly throughout the year. A comparative study of the larger prominences photographed in the years 1906–1908 at Mount Wilson and the Yerkes Observatory has been published by Dr. Abetti and Miss Smith.

Spectra of Sun-spots.

The study of the spectra of sun-spots is being continued regularly in so far as the low condition of the solar activity permits. This includes the determination of the polarity and strength of magnetic field of each spot, and of the penumbra surrounding it, and an investigation, by the aid of the spectroheliograph, of the configuration of the *Hα* flocculi in its vicinity.

An extended investigation of the motion and condition of calcium vapor over sun-spots and neighboring regions has been made by Mr. St. John during the past year and is being continued with the aid of the Snow and tower telescopes. In addition to the calcium lines, the D lines of sodium, the *b* lines of magnesium, and *Hα* will be included in the further study of this important question of the circulation of the gases in the vicinity of sun-spots. The results for calcium have shown that:

(1) In most sun-spots the calcium vapor is descending over the umbræ with velocities ranging from 0.7 km. to 2.2 km. per second for different spots.

(2) Over the penumbræ the vapor giving rise to bright K_2 has little if any vertical motion, while the vapor producing the absorption K_3 is descending with about the same mean velocity as over the general solar surface.

(3) This descending motion is true as well of the absorbing vapor over the flocculi and the regions immediately outside of the flocculi, while the emitting vapor over the flocculi shows a possible slight motion of ascent.

(4) A radial motion inward across the penumbræ is shown both by the emitting and the absorbing vapor, the latter moving with the greater velocity.

(5) Occasionally rotary motion around the umbræ of sun-spots is shown both by the emitting and the absorbing vapor. When this occurs the combination of the radial and the rotary motions results in a vertical motion directed toward the umbra, but the direction of rotation does not appear to depend upon the position of the spot in reference to the sun's equator.

In addition to this investigation of the motion of calcium vapor in and around sun-spots, Mr. St. John is engaged upon a study of the radial motions of the vapors in spots, an effect first discovered by Evershed. The following results are shown by the photographs already obtained:

(1) All of the vapors of the reversing layer and chromosphere are concerned in the movements.

(2) Of the high chromospheric vapors, viz, calcium, hydrogen, magnesium, and sodium, the calcium always, the hydrogen generally, and the magnesium and sodium frequently are flowing into the spots, as shown by the displacements of the strongest and probably high-level lines of these elements.

(3) The displacements of the other lines of calcium, magnesium, and sodium, and of the lines of the reversing layer, are in the opposite direction and indicate an outflow of the lower-lying vapors, the highest velocity of outflow being associated with the lowest levels, on the assumption that the weaker lines are produced at the lower levels.

Spectroscopic Observations of the Rotation of the Sun.

In accordance with a plan adopted at the fourth conference of the International Union for Coöperation in Solar Research, held on Mount Wilson in September 1910, the various observers engaged in working upon the rotation of the sun by spectrographic methods selected separate regions of the spectrum within which to carry on their investigation, at the same time uniting upon one region common to all observers for the purpose of comparison of results. The region selected in common extends from λ 4200 to λ 4300, and the two special regions selected for work at Mount Wilson are from λ 4500 to λ 4700, and from λ 5100 to λ 5300. During the year Mr. Adams has obtained a number of photographs in each of these regions, using the 60-foot tower telescope and the 30-foot spectrograph. Two different gratings have been employed with the latter instrument. The results of the measures of these plates by Miss Lasby are almost identical with those obtained at Mount Wilson in 1908 for the latitudes between 30° and the sun's pole. For the equator and latitude 15° the average result from the three regions is about 1 per cent less than that found in 1908. This is due in large measure to the low value given by the least refrangible region of λ 5100 to λ 5300, and it may perhaps be caused by the fact that the level of the lines measured in this region is lower than that of the lines in the more refrangible regions and the velocity given by them slightly less. The investigation will be continued with the 150-foot tower telescope when the latter is available.

Miscellaneous Investigations.

The question of the existence of free oxygen in the solar atmosphere has never received a definite answer, although a considerable amount of work has been done upon it. Recently Mr. St. John took up the study of the problem with the powerful 30-foot spectrograph and has been led to the following results:

(1) Of the two oxygen triplets in the principal series, upon whose presence or absence in the solar spectrum any definite conclusions must be based, the violet triplet beginning at λ 3947 does not appear to be present.

(2) An infra-red triplet present in the solar spectrum, beginning at λ 7772, has been found by means of a comparison of the opposite limbs of the sun to be of purely solar origin, the displacements shown being closely those given by known solar lines; but existing wave-length determinations of the oxygen lines, however, are not sufficiently accurate to make certain their identification with the solar lines. The wave-lengths of the oxygen lines will be determined accurately by photographic methods as soon as the instrumental equipment for producing a sufficiently bright light source showing the oxygen lines has been prepared.

In the course of this work Mr. St. John has proven that the great a and B and A oxygen bands present in the solar spectrum are of purely terrestrial origin, and has made a determination of the wave-lengths of the lines present in the a band to a high degree of precision on the international system.

The Observatory secured in July of this year a 6-inch plane grating made by Michelson, of the University of Chicago, which has been placed in the 30-foot tower spectrograph. The spectra obtained with this instrument are of such a high degree of excellence that it has seemed desirable to attempt with it, to some extent at least, the determination of the wave-lengths of the tertiary standards in the solar spectrum upon the international system. In addition to these wave-lengths the investigation will provide the values of the displacements of many solar lines due to the pressure of the sun's reversing layer.

A number of photographs of the flash spectrum have been obtained with this instrument by Mr. Ellerman.

THE 60-INCH REFLECTOR.

The principal addition to the equipment of the 60-inch reflector during the year has been the large three-prism spectrograph employed with the Cassegrain combination of mirrors at an equivalent focal length of 80 feet. This instrument was built by Gaertner, of Chicago, in accordance with designs made at the Observatory, and was installed on Mount Wilson in December of last year. The construction of the spectrograph is such as to admit of a wide variety of modifications, according to the brightness and character of the object to be photographed. The number of prisms may be varied from three to one, cameras with a focal length up to 40 inches may be employed, and the positions of the prisms may be varied to bring into minimum deviation any part of the visible spectrum. The instrument is of rigid construction, and is very well adapted for determinations of radial velocity, having an automatic temperature control and a comparison-spectrum apparatus providing for the use of the electric arc.

A number of changes and modifications have been made during the year in connection with the telescope itself. The principal one of these was the addition of a gear-train to the driving-clock in order to increase its power. It was found during the autumn of 1910 that the power was insufficient to drive the telescope satisfactorily in all positions with the considerable variations of weight upon the bearings involved in the use of different accessory instruments. By the addition of a gear-train to the driving-clock its power has been increased about 50 per cent and the difficulty has been removed completely. In addition, the base upon which the clock rests has been strengthened and made more rigid. Other minor alterations include the insertion of ball bearings in the slow-motion motors for moving the telescope in right ascension and declination, and strengthening of the fastenings of the cover of the large cast-iron flotation tank to prevent mercury leaks. A steel ladder curved to the form of the dome has been fastened near the shutter opening, in order to facilitate reaching the observing platform.

The Observatory now has under construction by the Union Iron Works of San Francisco an additional steel frame, or "cage," to be placed upon the end of the tube of the reflector in order to provide for work directly in the axis of the large mirror. The loss of light at the diagonal plane mirror will thus be avoided, an especially important consideration in studies upon ultra-violet spectra. This frame is planned to carry a small spectrograph for work upon stars below the seventh magnitude, a very short-focus, low-dispersion spectrograph for investigations of the spectra of nebulæ and star-clusters, and a quartz spectrograph of 2 inches aperture for ultra-violet spectra. The frame is designed to admit of the use of a plate-holder for direct photography as well.

Direct Photography.

The photography of the Kapteyn Selected Areas with and without absorption screens has been continued during the year by Mr. Fath, and is now practically completed. In addition a few plates have been taken with colored screens for the purpose of studying the possible effect of the absorption of light in space. Since observing conditions during the winter months as a rule are comparatively inferior, the direct photography of nebulæ and star-clusters was discontinued between the months of December and June, the additional time available being used for spectrographic work. In July a series of photographs of certain selected nebulæ and clusters was commenced by Mr. Pease, with a view to obtaining the material for a study of the stellar distribution within these objects. The photographs should prove of great value in the interpretation of the spectrographic observations.

Measures made under the direction of Professor Kapteyn of a few photographs taken at the primary focus of the reflector for the determination of stellar parallaxes indicate that, while the order of precision is high, the linear scale is insufficient for this very exacting type of work. Accordingly there is now under construction in the instrument-shop a large metal plate-holder and support, to be used at the 100-foot equivalent focus, and with the completion of this instrument the work will be taken up again.

Photographic Photometry.

The investigation of methods of determining photographic magnitudes with the 60-inch reflector has been continued throughout the year by Mr. Seares, and about 280 photometric plates have been secured by him. Of this number, 21 are of the North Polar Sequence and of the four secondary sequences at +15° declination, and 1, 7, 13, and 19 hours of right ascension. These were taken at the request of Professor Pickering and have been forwarded to the Harvard College Observatory for measurement.

The remaining plates relate mainly to an investigation of the diffraction effect that enters when the photographic magnitude scale is established through a comparison of exposures made with the full aperture and with diaphragms of various shapes and sizes, and to a study of the correction required by the observed magnitudes, which depends upon the distances of the individual stars from the axis of the instrument.

The diffraction effect has been studied from two different standpoints. The first depends upon an actual comparison of the magnitude scales established for the same region by a combination of results obtained with the full aperture of 60 inches with those given by diaphragms of 32, 14, 8, and 6 inches, a 60° sector-shaped diaphragm, a rotating sector, and a wire-gauze screen of known absorption constant. The agreement of the various magnitude scales thus derived is so close over a range of five magnitudes that the effect of the change in the diffraction pattern produced by reducing the aperture must be regarded as practicably negligible.

The second method is indirect and involves a determination of the effect on the size of photographic star-images produced by small errors of focus. From a long series of focal and extra-focal plates it was found that, on the average, an error of focus amounting to 0.125 mm. produces an increase in the apparent brightness of the stars photographed of 0.03 magnitude. The tenfold change in the size of the image produced by this error in focus is nearly the same as that produced by the use of a 6-inch diaphragm over the 60-inch mirror. While it is probable that the intensity distribution within the diffraction disk corresponding to an aperture of 6 inches is different from that in the cross-section of the full aperture cone at a point 0.125 mm. from the focus, it does not seem likely that this can affect the result greatly. Accordingly it appears that, even with the use of a diaphragm only 6 inches in diameter, the errors introduced will be of the order of 0.03 magnitude. The two methods used for the investigation of the diffraction effect are therefore in agreement in their results.

The examination of the plates taken for the study of the diffraction effect soon brought to light the fact that the correction to the observed magnitudes depending on the distances of the stars from the center of the plate is very large and variable from plate to plate. This led to an extended investigation of the circumstances which determine the magnitude of this error. The results are still incomplete, though various facts, which may be summarized as follows, have been established clearly:

(1) The distance correction is practically independent of small errors of focus, and of the kind, strength, time, and temperature of development.

(2) It depends upon the brightness of the star, or more specifically upon the size of the photographic star-image, being a maximum for the largest images and sensibly zero for the smallest. The effect is to increase the apparent brightness of the stars.

(3) The magnitude of the correction is also dependent in some way upon the individual star; two stars of the same brightness, and at the same distance from the axis, may require widely different corrections. Thus far it has not been possible to connect this phenomenon either with the color of the stars or with their positions on the plate.

(4) Aside from the variations in the corrections mentioned under 2 and 3, there are anomalous variations from plate to plate as yet unexplained, though there is some evidence that they may be due to small changes in the figure of the mirror resulting from variations in temperature.

The whole investigation has been laborious and tedious, and the final result, so far as the satisfactory determination of photographic magnitudes is concerned, is still somewhat problematical. There is reason, however, for believing that the various difficulties may be overcome.

STELLAR SPECTROSCOPY.

The three-prism spectrograph for use at the 80-foot focus of the large reflector, described briefly above, has been used for almost all of the stellar spectroscopic work for the year. A few photographs have been obtained with the small focal-plane instrument, but it has seemed desirable to delay any extensive series of observations with it until the new steel frame already referred to should be available. The considerable gain in light efficiency with this form of mounting should prove of especial advantage for work upon faint stars.

The program of stellar spectroscopic work with the Cassegrain spectrograph at the present time includes determinations of the radial velocities of two lists of stars: first, about 400 stars, mainly of types A and B, selected by Professor Kapteyn for the evidence which they will furnish concerning star-streams among the stars with these types of spectra; second, about 90 stars between magnitudes 5 and 7, mainly of the solar type of spectrum, for which the parallaxes and the proper-motions have been determined. In addition, photographs are being made of a small number of stars of type A with the object of making accurate studies of the character of their spectra. The Observatory will also take part in the general coöperative plan now under consideration at several observatories for the determination of the radial velocities of all stars between magnitudes 5.0 and 6.5.

Since December about 600 photographs of the spectra of nearly 200 stars have been obtained with the Cassegrain spectrographs by Messrs. Adams, Babcock, and Pease. Experience has shown that in the case of stars having spectra with few and, as a rule, ill-defined lines no gain in accuracy is obtained by increasing the linear scale of the photographs beyond a certain amount, while in extreme cases a distinct loss is suffered. After some experiments in this direction we have adopted provisionally a dispersion of two prisms used in conjunction with a camera of 18 inches focal length as most suitable for the study of the stars of types A and B and the fainter solar stars as well. Since the collimating lens in this instrument has a focal length of 40 inches, the combined optical train is very efficient as regards the purity of the resultant spectrum, a consideration of especial importance in photographing stars of the solar type of spectrum. The efficiency of the spectrograph when used in this form has been very satisfactory and fully up to our anticipations, in spite of the fact that the light undergoes four reflections at silver surfaces before reaching the photographic plate. Under good conditions fully exposed negatives of stars having a visual magnitude of 6.0 are obtained in an hour. The faintest star observed up to this time has a magnitude of 7.2 on the visual scale.

The difficult work of measuring and reducing the spectra, in many of which the lines are exceedingly faint and ill-defined, has been carried on by Mr. Adams, and Miss Lasby, Miss Waterman, and Miss Ensign, of the Computing Division. At the present time at least one measurement of each plate is available, and in most cases there are two or more. Among the results obtained we may refer to the discovery of about fifty spectroscopic binaries; of seven stars in which the hydrogen lines are bright; and of several stars, among which is one of type A, having radial velocities of over 100 km. per second. The application of the results to star-streams is referred to in connection with Professor Kapteyn's investigations.

Photographic Investigations of the Spectra of Globular Star-clusters and Spiral Nebulæ.

During the year Mr. Fath has obtained spectra of two spiral nebulæ, N. G. C. 3031 and 4736, with the low-dispersion spectrograph. The first of these shows a well-defined K-type spectrum, and in this respect differs from most spiral nebulæ, which are of the G type. The photograph of N. G. C. 4736 shows a G-type spectrum, thus confirming the result obtained from a previous negative. Spectrograms of the three globular clusters N. G. C. 5904, 6093, and 6234 show all of these clusters to be of the F type, a result agreeing with that found for nine clusters during the previous year.

This work upon spiral nebulæ and star-clusters will be continued under much more favorable conditions when the new cage for the 60-inch reflector is available. In addition to the gain of light obtained by saving reflections at two silvered surfaces, some changes will be made in the spectrograph itself which will assist materially in the same direction.

Professor Kapteyn's Investigations.

The principal part of the work of Professor Kapteyn this year has been a continuation of the investigation of the motions of the *Orion* stars. All of the stars for which both the spectra and the proper-motions are known with precision have now been included in the discussion. As a result of this additional material it now seems doubtful whether the conclusion arrived at last year, that the *Perseus* and *Scorpius-Centaurus* groups might represent the two great star-streams among the *Orion* stars, can be correct. In order to settle the question, the best plan seemed to be to include in the investigation the A stars, which, according to the generally accepted view at the present time, represent the next step in the order of stellar evolution. The result of this rather considerable extension of the work has been to show that the two groups just mentioned do not represent the two great star-streams, but that they must rather be considered as forming part of a single stream, in spite of the fact that their directions of motion differ considerably. To this single stream all, or nearly all, of the known *Orion* stars must belong.

This fact might at first seem highly surprising, since, for the other spectral types, the phenomenon of the two star-streams is so conspicuous a feature. A discussion of the A stars, however, shows clearly how this might occur.

According to the latest determination by Eddington, the numbers of stars contained in the first and second streams are in the ratio 3 : 2 for the second type stars, but 3 : 1 for the early A stars. The second stream, therefore, becomes relatively poorer the earlier the type of spectrum. It seems reasonable to conclude that the fact that almost all the stars of the *Orion* type, the earliest type of all, seem to belong to a single stream, must be due to the extreme poverty of the second stream. Since, however, it seems reasonable to expect that some traces of this stream must still exist, a careful search has been begun for stars which may belong to it. Partial success has already been obtained. There can hardly be any doubt that such *Orion* stars as 165 G *Canis Majoris, u Herculis,* Groombridge 2533, 12 *Lacertæ,* and 58 *Pegasi,* must belong to the second stream. As a definite conclusion can not in most cases be reached without a determination of the radial velocities, the search must necessarily proceed somewhat slowly.

At the present time the further probable results of the whole investigation may be summarized as follows:

As we pass from the stars of the solar type to those of type A and thence to the *Orion* stars,

(1) The parallelism of the motion of the stars in each of the two streams becomes more marked.

(2) The direction of the stream-motion, relative to the sun, changes gradually.

(3) The velocity of the stream-motion, relative to the sun, decreases gradually.

(4) The number of stars in the second stream, as compared with that in the first, decreases.

The certainty of these conclusions depends of course upon the reliability of the observational data on which they rest, and these, up to the present time, are for the most part very meager. For this reason a large number of stars of the *Orion* type and type A have been added to the radial velocity program of the 60-inch reflector. Should the data which we may expect to secure in a short time with this instrument confirm the provisional results given above, we shall learn some very significant facts as to the amount and direction of the relative motion of the two star-streams, facts which in turn promise to throw some light on the question of the origin of the two streams and that of the Milky Way itself.

In addition to the work upon the *Orion* and A type stars, Professor Kapteyn has devoted some time to working out parts of the program of the 60-inch reflector, giving especial attention to observations for the determination of the absorption of light in space.

At the request of Professor Kapteyn, Mr. Fath has been continuing throughout the year observations on the average brightness of different portions of the sky. In addition Mr. Fath has obtained with a low-dispersion spectrograph loaned by Director Campbell, of the Lick Observatory, two spectra of the brightest portion of the Milky Way in *Sagittarius*. The photographs were secured with exposures of 30 and 65 hours. The spectra appear to be approximately of the solar type, and may have been influenced to some extent by several bright stars of type K present in this region. The work will be continued, guarding so far as possible against this effect, in order to determine whether the A type of spectrum is predominant among the stars forming the Milky Way.

PHYSICAL LABORATORY.

The investigations carried on in the physical laboratory during the year have consisted of further studies of the Zeeman effect for several elements by Mr. King and Mr. Babcock, a determination by Mr. Gale of the displacements in the spectra of the arc and spark of the principal lines of iron and titanium at pressures between a partial vacuum and 16 atmospheres, and a study of furnace spectra under pressure by Mr. King.

The results of the investigation of the Zeeman effect for iron and titanium by Mr. King will be given in detail in Publication 153 of the Carnegie Institution of Washington, now in press. They are summarized briefly in the early part of this report, and are based upon a study of the behavior of over 1,100 lines between the limits λ 3660 and λ 6743.

Similar studies by Mr. Babcock of the Zeeman effect for chromium and vanadium have been completed and will also be published in detail. Mr. Babcock has carried out a comparison of the curves of frequencies of the occurrence of the magnetic separations for the triplets in the spectra of fourteen elements and has found a close similarity between the positions of maxima and minima. A careful determination of the value of $\Delta\lambda/\lambda_2$ for the two principal maxima gives for e/m (the ratio of ionic charge to mass) the quantity 1.775, a result in almost exact agreement with the mean values obtained by other observers by different methods. Mr. Babcock has made a number of experiments on the production of absorption lines in the magnetic field, in order to imitate more closely the effects observed in sun-spots.

The study of the Zeeman effect in the laboratory has been carried to a point at which the need of a more powerful field for the separation of very close components and the analysis of highly complex lines is felt greatly. Accordingly, a large electro-magnet of the Weiss pattern has been purchased during the year and is now being erected. This instrument is designed to give a field of about 46,000 gausses with a gap of 2 mm., and is provided with an efficient cooling system admitting of continuous operation during many hours.

Mr. Gale spent the months of March, April, and May in Pasadena and carried on an investigation of the displacements of the lines in the arc and spark spectra of iron and titanium under pressure. Most previous investigations have been made with comparatively high pressures and, accordingly, it seemed best to employ moderate and low pressures for this particular study, the more so in view of the fact that the pressures encountered in the solar atmosphere and in stars are of a moderate order of magnitude. The main results of the investigation have already been summarized. In addition to the direct study of the pressure effect, Mr. Gale examined the qualitative influence of gases of various sorts upon the intensities of the lines of different elements.

The study of the pressure effects for electric-furnace spectra was taken up by Mr. King primarily with the object of testing whether a source of radiation different in many respects from the arc and the spark would give results differing from those given by the latter sources. A considerable number of photographs for iron, titanium, and vanadium are now available, and the results appear to show consistently larger values for the furnace lines than for the arc lines at the same pressures. The displacements do not appear to vary throughout the range of temperature which it is possible to secure in the furnace. An interesting feature of the use of the furnace is the possibility of obtaining the pressure displacements of absorption lines by passing white light through the furnace when under pressure. The shifts found in this way are the same as those for emission lines. This line of work is still in progress.

The equipment of the laboratory has been increased during the year by the purchase of several electrical measuring instruments and a number of pieces of optical apparatus. A small concave grating of 1 meter radius has been secured for work requiring moderate dispersion.

THE COMPUTING DIVISION.

The Computing Division has remained throughout the year under the direction of Mr. Seares.

Miss Burwell continued during the autumn and winter of 1910 her study of the photographs of sun-spot spectra, giving especial attention to the effect upon the spectrum lines of the presence of the magnetic field. This has involved the classification of the lines in accordance with the system devised by Mr. Hale and outlined in the report of last year. A careful comparison of the spectra of α *Boötis*, α *Tauri*, and α *Orionis* with the sun-spot spectrum was also completed. During the summer months Miss Burwell was given leave of absence to carry on studies at the University of Chicago. She returned to Pasadena in September.

Miss Griffin continued, up to the time of her resignation July 1, the measurement and reduction of laboratory photographs and various investigations in photographic photometry. Her work included the determination of the separations of lines in the magnetic field for several elements and the displacements of lines under pressure in the electric furnace. In addition to 58 laboratory plates Miss Griffin carried out the measurement and reduction of 94 photometric negatives.

Miss Lasby has devoted the greater part of her time to stellar spectra, having measured and reduced 630 spectrograms during the year. About 550 of these were taken with the Cassegrain spectrograph and the remainder with the focal plane instrument. In continuation of the investigation of the solar rotation Miss Lasby has measured and reduced 18 photographs each covering 6 points of latitude. About 3 months was employed in the measurement of laboratory photographs taken by Mr. Gale of the spectrum of the electric arc and spark under pressure. Miss Lasby has also given some time to computations connected with the construction of tables designed to facilitate the reduction of stellar spectra.

Miss Smith has continued during the year her work upon spectroheliograph plates. This has included the determination of the areas of the calcium flocculi upon 204 negatives, making the reduction complete up to February 1, 1911. The curves showing the fluctuations of the areas of the flocculi and so indicating the variations in solar activity have been drawn to August 20, 1910. Miss Smith has measured, in addition, 269 prominence plates, completing the reduction of this series to June 18, 1911. Prints have been made of about 2,500 negatives, including all calcium and hydrogen spectroheliograms and direct photographs of the sun taken between April 1908 and June 1911. These have been classified and arranged in book form for purposes of reference in investigations of sun-spot and flocculi structure.

Miss Ware has been engaged during the greater part of the year in the reduction of solar spectra obtained by Mr. St. John. The majority of the photographs are related to a determination of the wave-lengths of the H and K lines in the spectrum of the chromosphere. Miss Ware has also measured over 100 plates in connection with the investigation of the Evershed effect in sun-spots, and has made a series of determinations of the wave-lengths of the oxygen lines in the a group of the solar spectrum on the international system. A considerable number of reductions, related for the most part to the work in stellar photometry, have been carried out by Miss Ware during the year.

The classification and reduction of stellar spectrograms has formed the larger part of Miss Waterman's studies during the year. About 600 photographs taken with the Cassegrain and focal plane spectrographs have been measured and reduced and the types of spectra represented by them have been determined. Miss Waterman has also devoted a considerable amount of time to the construction of a set of tables by means of which the constants of reduction for the Hartmann interpolation formula may be determined for any plate by simple inspection. Miss Waterman resigned from the Computing Division July 1, 1911.

Miss Martha Renner, who was appointed to the Computing Division February 1, 1911, has given her entire time, with the exception of that required for the investigation of the screw errors of one of the small comparators, to the measurement and reduction of photographs relating to investigations in photographic photometry with the 60-inch reflector. About 160 photographs have been measured by her, most of which were taken for the determination of the effect produced on photographic magnitudes by small changes in focus, and by the various conditions which affect the development of the photographic plate.

Miss Mary Wanda Sheldon was appointed to the Computing Division July 1, 1911, and Miss Inez A. Ensign August 1, 1911. Miss Sheldon will divide her time between the study of laboratory photographs and general computations connected mainly with stellar photometry. Miss Ensign is employing her entire time in the measurement and reduction of stellar spectra.

Miss Haines has remained in charge of the library as in the past. During the year the cataloguing of the unbound volumes and pamphlets has been completed. The accessions through purchase, since September 1, 1910, amount to 72 volumes, while, in addition, many valuable gifts have been received. During the year 282 volumes have been bound. The total number of bound volumes now in the library is 1,817.

CONSTRUCTION DIVISION.

The past year has been an active one as regards construction work, both in the instrument-shop and on Mount Wilson. As in previous years, the general supervision of the work has been in charge of the Director, with Mr. Pease in immediate charge of the design of the instruments, Mr. Ayers of the instrument-shop, and Mr. Jones of the construction work on Mount Wilson. Mr. Ritchey has been in charge of the optical work upon the 100-inch mirror, and Mr. Drew has had direct supervision of the design of the 100-inch telescope.

The principal work carried on in the instrument-shop during the year has been the large 75-foot spectrograph to be used with the 150-foot tower. The instrument has now been completed with the exception of a few minor details, and was installed on Mount Wilson during the month of August. It is designed for use either as a spectrograph or spectroheliograph, with a large variety of dispersive units, all of which are directly interchangeable. Thus the observer can by means of an electric motor bring into position beneath the collimating lens a prism of small angle, a prism of large angle, a diffraction grating, or two gratings side by side, according to the work to be undertaken. The instrument can be used at a focal length of either 30 or 75 feet, a hoisting apparatus having been arranged to raise the entire base with the various dispersive units to the 30-foot level.

The work of the instrument-shop during the year has included, in addition to the large spectrograph:

The construction of parts of the small stellar spectrograph for use at the primary focus of the 60-inch reflector, and of the quartz spectrograph.

The partial rebuilding of the driving-clock of the 60-inch reflector and various changes connected with it.

The construction of a mounting for a concave grating of 1-meter radius.

The construction of a water-distilling apparatus for use with the exhaust of the gas-engine in the Mount Wilson power-plant.

The construction of the hoisting device and the figuring of various grinding tools for use in the optical work upon the 100-inch reflector.

In addition many minor repairs have been made upon existing instruments.

THE 150-FOOT TOWER TELESCOPE.

At the time at which the last annual report was written the two lenses for use in the tower telescope had just been received. They were of triple construction and designed to reduce the effect of chromatic aberration to a minimum. A careful examination of these lenses in the optical testing-rooms in Pasadena indicated the presence of strong astigmatism and considerable spherical aberration, and accordingly they were returned to their makers for additional figuring. On further examination it was found that one of the components in each lens had indices of refraction unsuited for the purpose in view, and the attempt was made to procure new disks of glass of satisfactory indices. After a number of efforts in this direction without success, it was decided to give up the triple form of construction and resort to the ordinary doublet type. New lenses of this sort corrected visually were received in July of this year and tests showed a marked improvement over those tried previously. The 8-inch lens for use in the spectrograph has been accepted, but the image-forming objective of 12 inches aperture is still found to be subject to considerable zonal errors and has been returned to the manufacturers for further retouching.

With the exception of the image-forming lens, the 150-foot tower is now complete in all of its essential features, and in case of serious delay in the completion of the 150-foot objective, the lens now in use with the 60-foot tower will be employed in order to gain the advantages of the more powerful spectroscopic apparatus of the larger tower.

GENERAL CONSTRUCTION WORK ON MOUNT WILSON.

The plan of construction work on Mount Wilson during the summer has been influenced to a great extent by considerations relating to the 100-inch telescope. In order to provide for the concentration of building operations during the next few years around the great task of the erection of the 100-inch telescope mounting, it has seemed desirable to complete, in so far as possible during this year, all repairs and additions to the existing buildings of the Observatory, and to arrange for the necessary increase in equipment which the large instrument will require. As a result the building operations of the year have been of a very varied character. Among them I may refer to the following:

The Snow telescope house has been rendered essentially fire-proof, all canvas having been replaced by sheet iron, and the wooden roof replaced by a steel roof. The developing rooms in the basement of the building have been enlarged and reconstructed out of concrete.

A water-storage reservoir, built of reinforced concrete, with a capacity of 140,000 gallons, has been completed. Connected with this is a fire system consisting of 2-inch pipe with hydrants at all of the principal observatory buildings used in conjunction with a high-pressure pump. This should give efficient fire protection for almost any contingency that may arise.

A new camp house, near the location of the 100-inch telescope, has been provided for the use of the men engaged in the construction work. Also a storehouse built of sheet iron and a small building which may be used for sleeping quarters during stormy weather.

The 60-inch reflector dome and the 150-foot tower have been repainted and the canvas around the base of the reflector has been replaced by sheet iron. A small room has been built in the basement of the dome to serve as sleeping quarters for the night observer.

A 50-horsepower twin-cylinder gas-engine with a direct connected 40-kilowatt generator has been purchased for the power-plant and will be installed during the autumn. This will provide for all the requirements of the entire observatory equipment after the completion of the 100-inch telescope.

A large amount of general work has been carried on, including the erection of several concrete retaining walls, the laying of conduit for electric power and light, repairs of some of the observers' cottages, and grading at the site of the 100-inch reflector.

THE 100-INCH TELESCOPE.

In view of the difficulty experienced by the French Plate Glass Company in securing a thick disk of 100 inches aperture which should be free from air-bubbles and flaws, it seemed advisable in the autumn of 1910 to begin work upon the disk already received and temporarily laid aside. An inspection of this disk had shown that while there were well-defined sheets of air-bubbles running through the body of the glass, they did not approach the surface so closely as to interfere with securing a perfect paraboloidal figure. Furthermore, the glass as a whole seemed to be very firmly knit together, in spite of the presence of the bubbles. Since under these conditions the only obstacle to the perfect success of the disk as an astronomical mirror would lie in the presence of strains in the glass which would prevent it from maintaining its figure under different conditions of temperature, it appeared well worth the relatively moderate cost of the necessary optical work to investigate this question. By the kindness of the French Plate Glass Company the Observatory is permitted to do this work on trial, payment for the disk being conditioned upon its proving suitable for use as an astronomical mirror.

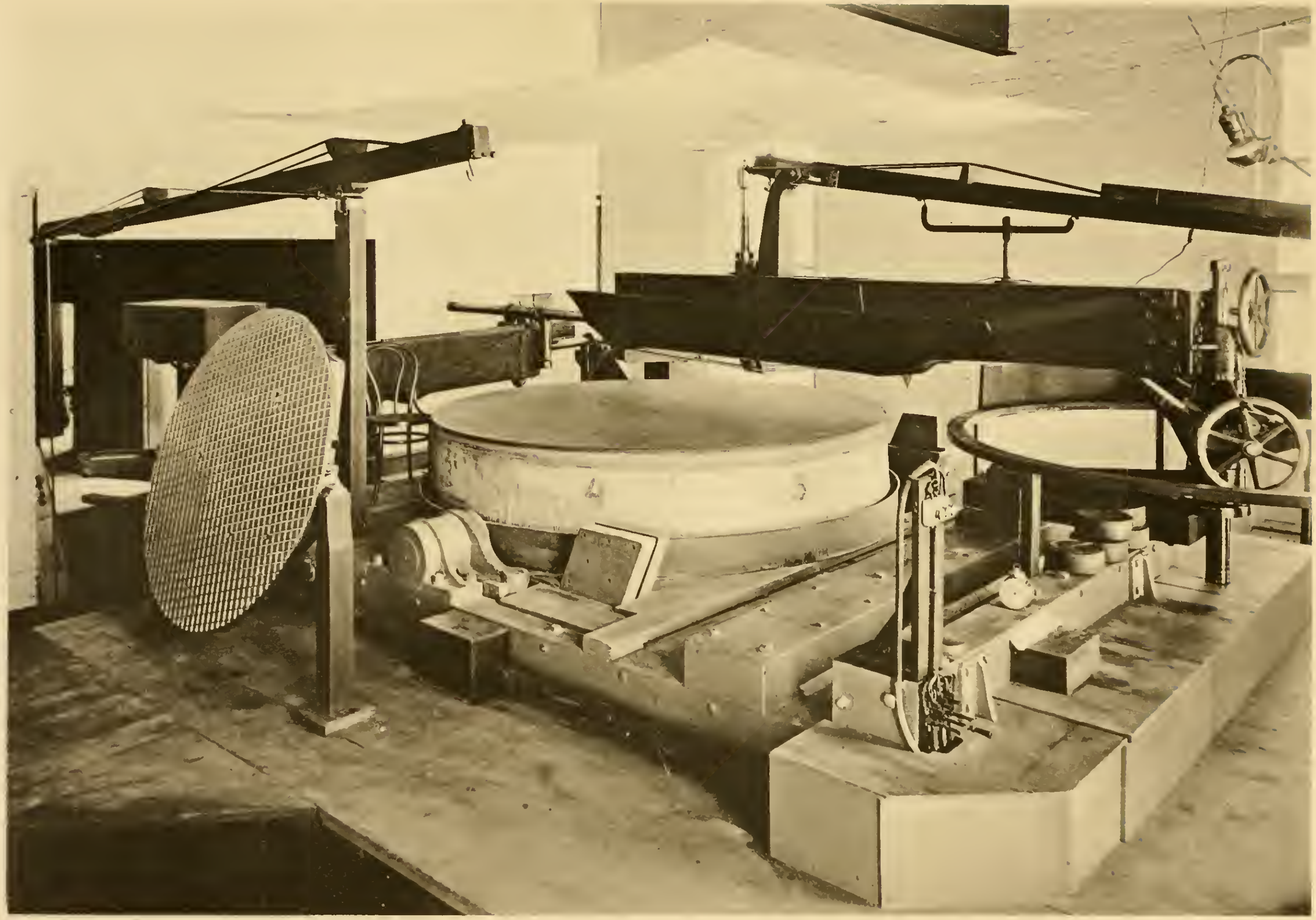
The process of figuring the disk, although delayed by illness upon the part of those engaged in the work, has been continued steadily, and at the present time the fine grinding of the spherical surface has been completed. As soon as the polishing is finished a series of tests will be undertaken to determine the character of the figure at different temperatures. So far as it is possible to judge, no changes have taken place in the flaws contained in the glass during the severe pressure put upon it by the process of rough grinding. The disk is being figured with a ratio of focal length to aperture of 5 to 1.

While this work is being carried on in Pasadena, the French Plate Glass Company is continuing at St. Gobain the attempt to cast a disk which shall be free from flaws and air-bubbles. The chief difficulty encountered in recent trials has been that of annealing in such a way as to keep the temperature of the entire body of glass uniform. Owing to this cause a second disk cast early in this year broke in the annealing oven. In the course of their experiments the St. Gobain company have succeeded in producing a flawless disk 100 inches in aperture and 20 cm. thick. It is possible that in case of necessity such a disk could be employed for the 100-inch telescope, provided it were figured in place upon the support system with which it was to be used finally.

With the aid of a special grant from the Carnegie Institution of Washington the work upon the design of the mounting has been carried on actively during the year. Mr. Drew has been in immediate charge, assisted during a part of the year by Mr. Le Grand. During the months of July and August Prof. Albert Smith, of Purdue University, acted as consulting engineer upon the structural design of the polar axis, tube, and building. At the present time the essential features of the design have been thoroughly worked out, and it should be possible to begin detailed drawings during the winter.

Reference has already been made to some of the construction work upon Mount Wilson, in connection with the plans for the erection of the 100-inch telescope. This has included the grading and leveling of the site, the construction of several small buildings for housing the machinery employed in the work, and the erection of a few of the smaller piers. A large amount of material for the main pier has been collected ready for use in the coming summer.

The Observatory chronicles with deep regret the death of Mr. John D. Hooker at Los Angeles, May 24, 1911. It was by the generosity of Mr. Hooker that funds for the purchase and construction of the 100-inch mirror were provided originally. His active and intelligent interest, not only in the progress of this work but in the activities of the Observatory as a whole, will be missed greatly by the members of the staff.



The 100-inch disk on the grinding machine, ready for polishing.

NUTRITION LABORATORY.*

FRANCIS G. BENEDICT, DIRECTOR.

The past year has witnessed an unusually active interest in the laboratory on the part of coöperating and visiting investigators. The construction of new apparatus and the improvement of apparatus already in use have added materially to our equipment, while the experimental researches have led to the accumulation of a large amount of important data with regard to a number of questions of fundamental importance in both physiology and pathology.

ADDITIONS TO EQUIPMENT.

The wisdom of constructing one large room without obstructing columns or piers and provided with arrangements for cooling and drying the air for use in calorimetric research has been fully justified in the past three years of experimenting; indeed, during the warmer months, the tendency has been to move to this room all researches in the building that can possibly be transported, and thus utilize the equable temperature and admirable humidity conditions. To facilitate this as much as possible, the available floor-space in the room has been increased materially during the last year by the addition of another balcony, somewhat larger than the one constructed a year ago. By this means it will be possible in future to conduct a larger number of researches in the calorimeter room during the warm weather; additional desk-room is also provided for one or more associates during the winter, thus permitting a more direct personal supervision of the researches in the calorimeter room than can otherwise be had.

ALTERATIONS IN THE RESPIRATION CALORIMETERS.

In an effort to minimize all possible sources of error in the calorimetric researches, it was found that the structural-steel framework of the respiration calorimeters has a capacity for holding or absorbing heat, thus affecting to a certain extent the heat measurements. In some of the calorimeters this interior framework was directly connected with the outer air through bolts or pieces of structural steel. It was assumed that the slight temperature differences between the inside of the chamber and the room air, namely, 2° or 3°, would not result in a material conduction of heat; but with the greater accuracy now striven for, it was deemed desirable this past winter to completely isolate the structural-steel framework by using rock-maple supports, and thus insure a perfect insulation from the room air. This insulation has been carried out on three of the calorimeters with the highest degree of success.

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* Situated at Boston, Massachusetts. Grant No. 681. $30,378 for investigations and maintenance during 1911. (For previous reports on work in nutrition, see Year Books Nos. 2–9.)

Among the important points developed this year was the desirability of using a thermostat for maintaining an absolutely constant temperature inside the calorimeter chambers when they are not in use. With this constancy of temperature, any one of the calorimeters may be opened at a moment's notice, a subject placed inside, and an experiment immediately begun without the delay incidental to a preliminary warming or cooling of the chamber.

As a result of the extensive research in body-temperature measurement made by Mr. E. P. Slack, of this Laboratory, an arrangement of thermo-elements has been applied to the calorimeters for measuring the rectal temperatures of subjects, so that a measurement of the body temperature may be obtained with great accuracy simultaneously with the measurement of the products of metabolism.

BICYCLE ERGOMETER.

The bicycle ergometer described by Benedict and Carpenter* was so successfully used in the respiration-calorimeter experiments on muscular work at Middletown, Connecticut, that a duplicate of the apparatus was considered desirable for the Nutrition Laboratory. This has been constructed in the machine-shop during the past year, and at present is undergoing rigid and critical tests.

RESPIRATION APPARATUS.

The small respiration apparatus for nose or mouth breathing, which has been in process of development in the laboratory for the past three years, has proved so successful that several have been constructed during the winter and are now in active and continuous use.

Method of determining oxygen.—The amount of oxygen admitted to the system of the respiration apparatus was determined originally by measuring the loss in weight of a small cylinder of the highly compressed gas. This method was very successful and is recommended for isolated plants. Recently, however, a new method has been used in which the amount of oxygen admitted to the system is recorded on an extremely exact gas-meter, completely immersed in water and carefully calibrated by special tests. By this means the weighing of the oxygen cylinders can be dispensed with, thus greatly facilitating the manipulation of the apparatus, with no sacrifice of accuracy. The results have been so satisfactory that this method of measurement will in future be used on all of the respiration apparatus in the laboratory.

Absorbers for carbon dioxide and water.—As a logical outcome of the development of the absorbing system used in connection with the large respiration chamber of the calorimeter, we have been accustomed to employ a silver-plated can containing soda lime for absorbing carbon dioxide, and the lower part of a so-called Kipp generator filled with pumice-stone to absorb the water from the air-current. Recently an ordinary wide-mouth chemical bottle, fitted with metal pipes passing through a solid rubber stopper, has been substituted for the silver-plated can. This has proved very successful and can be prepared for use and cared for much more easily than the old form of carbon-dioxide absorber. The blown-glass water-absorber devised by Dr. H. B. Williams, formerly of Cornell Medical College, New York, has proved of such value that a large number have been ordered and are now in regular use in all of the respiration apparatus in this laboratory. Both of these substitutions contribute very materially to the facility of manipulation without a sacrifice of accuracy.

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* Benedict and Carpenter: U. S. Dept. Agr., Office Expt. Stas., Bul. 208, 1909.

A METABOLISM CAGE FOR DOGS.

For use in experiments on dogs, it was necessary to devise metabolism cages with suitable arrangements for saving the excreta. One of these cages has been built by the construction force of the Nutrition Laboratory on the plan devised by Prof. William J. Gies.

RESPIRATION APPARATUS FOR DOGS.

Many problems in the metabolism of animals may be satisfactorily studied, or at least investigated in a preliminary way, by the determination of the carbon dioxide alone without recourse to the more expensive and time-consuming determinations of the oxygen consumed and heat eliminated. In the two dog-respiration apparatus referred to in the last annual report, the amount of carbon dioxide eliminated by the dog was determined by measuring the increase of the carbon dioxide in the closed volume of air in the sealed chamber. As this principle involved the use of an extremely accurate gas analysis, the absorption system of the respiration apparatus for men was combined with the dog-respiration chamber. By means of this absorption system, a current of air is continually withdrawn from the chamber, the carbon dioxide and water absorbed, oxygen added to replace the amount used by the animal, and the air returned to the chamber. The total amount of carbon dioxide produced by the animal is weighed at the end of every half-hour or hour period. By substituting a double-valve device at each end of the absorption system, it is possible to keep the motor in continuous operation, since with a simple movement of the hand the air-current may be deflected from one set of purifiers to the other. With this device there is no necessity of stopping the motor, disconnecting the purifying vessels, and starting the motor again—a process which is liable to disturb the dog. This absorption method of determining the carbon dioxide after careful tests has been adopted for use with both the small and the large dog-respiration chambers, and two series of experiments with dogs are now in daily operation in this laboratory.

The method of obtaining a graphic record of the muscular activity of the dog has been somewhat modified the past year in such a way as to increase its efficiency; the great importance of such a record has been further demonstrated in the recent researches. As is clearly shown by the kymograph records, even in a state of rest there is considerable minor activity; and when the curves are compared with the measurements of the metabolism, the influence of such activity is very evident. It may be safely said that without this graphic record of the muscular activity, the results obtained for the metabolism have but little value.

RESPIRATION APPARATUS FOR INFANTS.

With a view to studying the metabolism of infants, a respiration chamber was devised in which, by means of a movable bed or crib, a record could be obtained of the slight movements of the child. This chamber can be attached to any one of the numerous motors in the laboratory accompanied by purifying devices, and the total carbon dioxide produced by the infant can thus be accurately measured. The apparatus has proved very successful and a number of experiments have already been made with it.

VACUUM DRYING APPARATUS.

The desirability of avoiding high temperatures in desiccating compounds of physiological importance has long been recognized, and accordingly a double-valved Geryk high-vacuum pump, connected with special forms of large-sized desiccators, has been installed in the laboratory. The pump is substantially placed against a heavy partition wall in the machine-shop and is driven by a belt from one of the line-shafts. A pipe leads to a battery of three large-sized desiccators in one of the other basement rooms. By this means the compounds can be dried over sulphuric acid in a high vacuum at room temperature, and the inevitable changes in composition incidental to high temperature avoided.

COOPERATING AND VISITING INVESTIGATORS.

In the researches in diabetes mellitus now in progress, Dr. E. P. Joslin has been actively interested, and, together with his associate, Dr. F. A. Stanwood, has contributed much to the success of these investigations.

Dr. John Homans has continued throughout the year his investigations on the influence of the removal of the hypophysis, and the results of his researches are about to be prepared for publication.

A study of the metabolism of normal babies has been begun through the interest and active cooperation of Dr. Fritz Talbot, of Boston. He has been able to secure a number of breast-fed babies for subjects, and has personally devoted much time to a careful study of the problems involved.

After several years of active experimenting on the influence upon metabolism of the removal of the pancreas or of ligating the pancreatic ducts, Dr. Joseph H. Pratt has cooperated with the Nutrition Laboratory in an investigation upon the digestibility and specific dynamic action of protein ingested by dogs from which the pancreas has been removed. In connection with his associate, Dr. L. H. Spooner, these researches have been well established and are now nearing completion.

With a view to making a practical application of his observations on the renewal and regeneration of air in submarines, Passed Assistant Surgeon

E. W. Brown, of the United States Navy, spent some weeks at the laboratory during the summer, investigating methods of gas analysis and discussing the question of the regeneration of air. He also carefully inspected the numerous forms of apparatus in the laboratory in which closed volumes of air are used for respiration purposes.

Prof. H. Monmouth Smith, of Syracuse University, spent several weeks at the laboratory acquiring the technique of respiration experiments with a view to prosecuting researches on athletes at Syracuse University.

STAFF NOTES.

The importance of the researches on blood, gas analysis, and respiration carried out at the University of Oxford by Dr. J. S. Haldane, and at the University of Cambridge by Dr. Joseph Barcroft, warranted arrangements for study at both of these universities by Mr. H. L. Higgins, of the Laboratory staff. Not only these two investigators, but also Drs. Bohr, Henriques, Krogh, and Hasselbalch, in Copenhagen, accorded Mr. Higgins every opportunity for becoming thoroughly familiar with the methods and technique which have been particularly well developed in these places. Mr. Higgins secured much valuable apparatus and was able to materially augment our valuable collection of reprints by separates of publications which were kindly given him by the various investigators that he came in contact with.

Later in the winter, Mr. T. M. Carpenter, of the Laboratory staff, made an extended tour of Europe, visiting particularly the northern countries and becoming more familiar with certain laboratories and researches which were not included in a trip taken by him three years ago. It is of special interest to note that this was highly appreciated by foreign investigators, who have freely written of their pleasure in being given the opportunity to become familiar with Mr. Carpenter's technique in calorimetric researches.

INVESTIGATIONS NOW IN PROGRESS.

METABOLISM OF NORMAL WOMEN.

With the accumulation of material in regard to pathological cases, it is obvious that the results for normal individuals are as yet too few to permit the most detailed and satisfactory comparison; consequently, it has been the policy of the Laboratory to secure as many observations on different normal individuals as possible. Fortunately, through the interest of Prof. Alice F. Blood, of Simmons College, we were enabled to study the normal metabolism of young, healthy, normal women, who volunteered as subjects for respiration calorimeter experiments. The results are of great value and will be a positive contribution to our knowledge of the metabolism of healthy young women, supplementing in an admirable way the researches instituted a year ago, in which many of the women members of the Laboratory staff volunteered as subjects. Mr. L. E. Emmes is continuing these studies as opportunity offers.

THE METABOLISM OF NORMAL INFANTS.

The increasing importance of studying the metabolism of infants in disease has led to a great desire on the part of physicians for information regarding the normal metabolism of both breast-fed and bottle-fed infants. Dr. Fritz B. Talbot, of Boston, has taken great interest in this problem, and has instituted a series of researches with an especially accurate respiration apparatus for studying the carbon-dioxide production of infants. The research has proceeded sufficiently to show that apparently minor muscular movements, such as a slight change in position of the hands or feet in an otherwise apparently perfectly quiet infant, may result in an enormous increase in the metabolism. The graphic records of body movements secured by means of the suspended crib inside the chamber have proved of invaluable assistance in interpreting the metabolism, and have led to fundamentally new conceptions regarding the influence of minor muscular exercise upon the metabolism of infants. It is proposed to undertake the investigation of pathological cases in the near future.

INFLUENCE OF THE INGESTION OF FOOD ON METABOLISM.

The fact that after the ingestion of food there is a noticeable rise in the heat production, carbon-dioxide elimination, and oxygen absorption, has not been denied by any investigator. But opinions vary widely when an attempt is made to explain the cause of this rise. The problem has been under observation for several years, both here in this laboratory and formerly in the chemical laboratory at Wesleyan University, in Middletown, Connecticut. In the research carried out in the Nutrition Laboratory the past year, special emphasis has been laid upon the influence of the ingestion of various kinds and amounts of carbohydrates. Both the respiration calorimeter and the respiration apparatus have been successfully employed, although the latter has been used more frequently. The research is far from complete, however, and active experimenting is in progress nearly every day.

SIMULTANEOUS STUDY OF BODY TEMPERATURE.

The simultaneous study of temperature in different parts of the body, referred to in the previous report, has been conducted during the past year by Mr. Edgar P. Slack. For this research, specially devised thermo-electric thermometers were used in connection with a constant-temperature oven, and simultaneous observations were made of the temperature in the mouth, rectum, and vagina, and in various superficial cavities, such as the axilla and groin. The thermal gradient of the body was also studied, and the results of measurements with the clinical thermometer and with the thermo-electric thermometer were compared. The research showed that, with the exception of the skin temperature, a rise or fall in temperature in any part of the body is accompanied by an equal rise or fall in temperature of the other parts of the body. Incidentally, many other points of interest regarding body temperature were brought out, especially with reference to the thermal gradient and the inaccuracy of clinical thermometers for observations requiring exact measurements. The results of the research have been prepared for publication and are now in press.

COMPARISON OF METHODS FOR STUDYING THE RESPIRATORY EXCHANGE.

In consideration of the vast amount of research carried out by the Zuntz-Geppert method of studying the respiratory exchange, the development of a method by Chauveau and Tissot, and the method and respiration apparatus developed in this laboratory, a strict comparison of the several methods now in existence for studying the respiratory exchange has seemed desirable. As a standard in this comparison, it is proposed to use the results of experiments with the bed calorimeter, in which the respiration is absolutely normal and quiet; experiments will then be made with the same subjects, in which the various types of breathing appliances and respiration apparatus will be used. Mr. T. M. Carpenter is continuing this most important and fundamental study, and the results are being looked forward to with great interest by a number of European scientists.

METABOLISM IN DIABETES.

The most important research in pathological metabolism now in progress at the laboratory is the continuation of the investigation instituted by Dr. E. P. Joslin on diabetes mellitus. Particular attention has been given during the past year to the study of serious and advanced cases with young children and to the influence of the so-called "oatmeal cure." Both of these problems are extremely complex and require many experiments before drawing any final conclusions. Furthermore, the most suitable experimental material is not so readily available as is the more general type of diabetes, and hence the investigation has not progressed so rapidly as did the earlier research on the general problem. The experiments are, however, of even greater interest than any heretofore carried out, especially as each experiment is made so far as possible a noticeable advance in accuracy and in completeness over the preceding one. In studying this problem, the supplementing of experiments with the respiration calorimeter by experiments with the respiration apparatus has proved highly advantageous, and it has been found perfectly feasible to make concurrent observations with both forms of apparatus and secure results of great pathological importance.

RELATION BETWEEN THE HYPOPHYSIS AND METABOLISM.

Owing to the interest of Dr. John Homans, of the department of surgical research at the Harvard Medical School, an investigation was begun a year ago on the influence of the removal of the hypophysis upon metabolism. The possibility of a relationship between the hypophysis and diabetes first justified the undertaking of the study of this obscure gland in the Nutrition Laboratory, and this research seems to be more promising of results than at first sight appeared probable. It is of special interest to note in this connection that the recent remarkable observations of Dr. Harvey Cushing, of Baltimore, to the effect that the removal of the hypophysis increased enormously the sugar tolerance of dogs have shown that in all probability there is some intimate relationship between this gland and sugar metabolism. In the investigation at the Nutrition Laboratory the observations have been confined to the total metabolism as measured by the carbon-dioxide production, both before and after the removal of the gland. A number of important observations have been made on different dogs, and the first report on this research will be prepared and issued shortly. The study of the sugar tolerance of two women whose metabolism was supposed to be influenced by an abnormal hypophysis has also been made, and future studies are planned with reference to the relationship between sugar tolerance and the hypophysis.

THE INFLUENCE OF THE INGESTION OF PROTEIN ON METABOLISM IN DOGS WITH DEFICIENT NITROGEN ASSIMILATION.

Through the kindness of Dr. Joseph H. Pratt, two dogs from which the pancreas had been removed by Dr. F. T. Murphy were made available for a study at the Nutrition Laboratory of the influence on metabolism of varying quantities of meat. These dogs, which had been actively studied for several years by Dr. Pratt, have a very low assimilation for protein, absorbing but 25 to 30 or 40 per cent of meat ingested. Under these conditions the opportunity presented for studying the influence of the ingestion of food on metabolism is ideal. According to the views of some investigators, the increase in metabolism following the ingestion of food is due to the work of digestion, movements of the intestinal tract, and the glandular secretion. According to other investigators, it is due to the specific dynamic action of protein; *i. e.*, something is absorbed out of the protein of the food, which is carried through the blood-circulating system and there stimulates the cells to greater activity. Inasmuch as these dogs had a deficient protein assimilation, it was believed that the work of digestion would be somewhat greater than normal, since a larger bulk of food would necessarily be forced through the intestinal tract. If, therefore, the work of digestion increases the metabolism, we should expect a larger heat output than with normal dogs. On the other hand, if the increase in metabolism is due to the specific dynamic action of protein, we should expect to find the results only about one-third of normal, since the assimilation of protein by these dogs is approximately one-third the assimilation by normal dogs. The results are not yet ready for drawing final deductions, however, and the experiments are still in progress.

THE CALIBRATION OF THE BICYCLE ERGOMETER.

In connection with the researches at Wesleyan University, a special form of bicycle ergometer was devised and used, and the results obtained with it have been published. At that time the calibration of the bicycle ergometer was carried out by means of a respiration chamber, which was much too large for the best results with an instrument of this kind. Recently a careful study of the mechanical and electrical features of this ergometer has brought out a number of theoretical points of great practical importance, which have justified a recalibration of the apparatus on a much more extended and accurate scale. Through the courtesy of Dr. C. F. Langworthy, of the U. S. Department of Agriculture, an ergometer has been loaned to the Nutrition Laboratory to be duplicated and for calibration. The apparatus, which is practically a stationary bicycle, is calibrated by placing it inside the chair calorimeter, rotating it from the outside by means of a flexible shaft, and measuring the heat actually produced. An extended series of tests was made, not only with this apparatus, but with a duplicate ergometer constructed in the laboratory machine-shop.

THE DETERMINATION OF SUGAR IN DIABETIC URINE.

The numerous clinical methods for determining sugar in diabetic urine have proved inadequate for the accurate studies which are to accompany the research on metabolism in diabetes now being carried out in the Nutrition Laboratory. Accordingly, Dr. A. W. Peters has been occupied during the past year in developing and modifying a number of methods for determining sugar, with a view to selecting, or devising if necessary, the most accurate and rapid method for the determination of sugar in pure-sugar solutions, and of reducing power in pathological urines. An especially critical study has been made of the estimate of sugar by the method of copper reduction, particularly the conditions affecting the reduction process and the quantitative determination of the copper involved. From the results obtained a procedure has been devised which is satisfactorily rapid and gives a high degree of accuracy in the determination of sugar in both diabetic urines and sugar solutions. Throughout the study, correct and delicate copper analysis was regarded as the chief means of investigation, and in this connection some results were obtained which are of critical importance for the accuracy of a sugar determination as well as of some general interest in copper analysis.

ANALYSES OF OUTDOOR AIR.

The Nutrition Laboratory is fortunate in being supplied with probably the most accurate type of gas-analysis apparatus in existence, namely, a modification of an apparatus devised by Pettersson, according to plans of Dr. Klas Sondén, of Stockholm. This has been in constant use for the past three years in the laboratory, and in the hands of Miss Alice Johnson has given extremely accurate results. One fundamental error, however, inherent in all methods of gas analysis as yet developed, has shown itself to be likewise inherent in this apparatus, although the other errors have been reduced to a minimum. A year ago we were firmly of the opinion that there were considerable fluctuations in the composition of outdoor air with particular reference to the oxygen content—fluctuations that were wholly inexplicable—but during the past year's research, in which a control has been established by the analysis from day to day of samples of a cylinder of compressed air secured from the laboratory of the Massachusetts Institute of Technology, we have found that when a correction is made for the error referred to our analyses show that the outdoor air remains remarkably constant in composition with regard to both the carbon-dioxide content and the oxygen content. The results of the research will be prepared for publication shortly.

Samples of air taken by Messrs. Carpenter and Higgins while on their ocean voyages and samples of air kindly forwarded by Drs. Haldane, Douglas, and Yandell Henderson from Pikes Peak are now being analyzed.

PUBLICATIONS.

The following have been prepared and issued during the past year:

(1) The influence of the preceding diet on the respiratory quotient after active digestion has ceased. Francis G. Benedict, L. E. Emmes, and J. A. Riche. Amer. Jour. Physiol., 27, p. 383. 1911.

It has commonly been believed that 12 hours after the ingestion of food, active digestion ceases and that then the oxidating processes of the body result in a combustion of body material. With the same individual, therefore, the kind of material oxidized 12 hours after the last food is taken would be expected to remain essentially constant. This may be determined by measuring accurately the carbon dioxide excretion and the oxygen consumption, the ratio between these two—the so-called respiratory quotient—being a very important index as to the character of the material oxidized. In order to study the influence of the preceding diet on the respiratory quotient after active digestion has ceased, a series of experiments was planned in which the last meal of the day before contained a large or small proportion of carbohydrates. The respiratory quotient as determined the next morning, or 12 hours after these diets, showed noticeable differences in the character of the material burned, being almost invariably much higher, indicating a carbohydrate combustion after a meal high in carbohydrates and lower after a meal low in carbohydrates. In these experiments, which were made with seven different subjects, both the small respiration apparatus and the respiration calorimeter were used. The results of the experiments permit many interesting theoretical considerations as to the ratio of carbohydrate material, *i. e.*, glycogen, in the body. A number of suggestions are made in this paper with reference to further experimental work.

(2) The respiratory exchange as affected by body position. L. E. Emmes and J. A. Riche. Amer. Jour. Physiol., 27, p. 406. 1911.

In order to secure the minimum metabolism of man for purposes of comparison, the gaseous metabolism has been usually measured when the subjects are lying with muscles relaxed on a couch. For the purpose of obtaining data regarding the metabolism of a subject in the sitting position, as compared with his metabolism when lying down, some 16 experiments were made with two young men as subjects. The results showed that the average pulse-rate rose from 63 when the subject was lying down to 71 when he was sitting, the carbon dioxide increased 4.3 per cent, and the oxygen consumption 7.6 per cent. The authors conclude that the difference in metabolism is due primarily to difference in internal muscular activity necessitated by the sustaining of body parts. Accordingly they infer from these tests that if it were possible so to support the body of a subject in a sitting position that the pulse-rate would be no greater than when the subject was lying down, the metabolism would be essentially the same in both positions.

(3) The energy metabolism of mother and child just before and just after birth. Thorne M. Carpenter and John R. Murlin. Archives of Internal Medicine, 7, p. 1. 1911.

A series of 31 metabolism experiments upon 3 parturient women was carried out by means of the bed respiration calorimeter, and are reported in this paper. The total metabolism as measured by the respiratory exchange and the heat production was periodically determined on all 3 subjects in a fasting condition within two weeks of the birth of the child, and also within 48 hours after parturition. In some of the experiments after the birth of the child, the metabolism of the mother alone was measured. During the period covered by the experiments, the subjects were kept in a local hospital and upon a constant diet. The pulse, respiration, and body temperature were obtained daily at the hospital, as well as during the experimental periods with the calorimeter. It was found that the metabolism of mother and child before and after parturition was the same in total amount; but, expressed per unit of body-weight, the metabolism of the newly delivered woman was about 7 per cent higher than that of the same woman before the birth of the child, and the metabolism of the pregnant subject was slightly higher than that of normal women. Considered per unit of surface, the pregnant woman had a higher metabolism than the non-pregnant, and the newly delivered woman higher than either. The total metabolism of the child alone per unit of weight, which was found by deducting the amount of the metabolism of the mother from that of the mother and child, was about two and one-half times that of the mother. Expressed per unit of surface, the metabolism was not greater than that of the nursing mother, but higher than that of the non-pregnant woman.

(4) Effects on men at rest of breathing oxygen-rich gas mixtures. Francis G. Benedict and Harold L. Higgins. Amer. Jour. Physiol., 28, p. 1. 1911.

The extensive bedside use of oxygen in therapy and the use of oxygen-rich atmospheres in diving appliances, rescue-saving apparatus, and in the regeneration of air in submarines lend additional interest to a study of the question as to whether or not there is an increased or decreased absorption of oxygen with oxygen-rich mixtures. In the extensive series of experiments reported in this paper, the oxygen consumption was determined when the subjects were breathing ordinary air; also when breathing atmospheres containing varying quantities of oxygen, namely, 40, 60, and 90 per cent. The results expressed in the following table show that essentially the same amount of oxygen was absorbed whether ordinary air was breathed or atmospheres containing 40 per cent, 60 per cent, or even 90 per cent of oxygen:

Percentage comparison of oxygen absorbed in experiments with different tensions.

Subject.	20 per cent of oxygen.	40 per cent of oxygen.	60 per cent of oxygen.	90 per cent of oxygen.
	p. ct.	*p. ct.*	*p. ct.*	*p. ct.*
T. M. C	100	102.0	.....	100.5
J. J. C	100	98.0	100.0	99.5
A. G. E	100	99.5	100.5	98.5
L. E. F	100	103.0	.....	100.5
H. L. H	100	.....	100.5	99.0
D. J. M	100	100.0	98.0	106.5
Average of all subjects	100	100.5	99.8	100.8

The paper concludes with an extensive discussion of the physiological sources of error in the method used, and the mechanics of respiration and circulation as affected by the breathing of high oxygen. The significance of oxygen in therapy is considered, and suggestions for further research complete the paper. The results are summarized as follows:

In experiments with normal individuals lying at complete muscular rest, 12 hours after the last meal, and breathing 40 per cent, 60 per cent, and 90 per cent oxygen mixtures, the authors find:

(*a*) There is no apparent difference between the metabolism as indicated by gaseous exchange (*i. e.*, the carbon-dioxide output, oxygen consumption, and respiratory quotient) and the metabolism when breathing ordinary air.

(*b*) There is no change in the respiration, either as to character, depth, or frequency, as compared with the same factors when breathing ordinary air.

(*c*) The pulse-rate is lower with oxygen-rich mixtures than when breathing ordinary air; furthermore, the higher the percentage of oxygen breathed (up to 90 per cent) the lower the pulse-rate.

(5) A respiration apparatus for the determination of the carbon dioxide produced by small animals. Francis G. Benedict and John Homans. Amer. Jour. Physiol., 28, p. 29. 1911.

Many problems in metabolism can only satisfactorily be studied by a measurement of the total carbon-dioxide output, oxygen intake, and heat productions. On the other hand, for a preliminary survey of a field of study in metabolism, the carbon-dioxide determinations alone are many times of great value. Since these can be obtained with the expenditure of much less time and money than the determinations of the oxygen consumption and the heat production, it follows that an apparatus in which the carbon dioxide can be determined with relative ease will be of great value in connection with metabolism experiments. The closed-chamber type of apparatus in which the carbon dioxide is allowed to accumulate, samples of air withdrawn from time to time, and the increment in the carbon dioxide calculated, was successfully used in the experiments reported in this paper. The carbon dioxide determinations were readily made by means of the excellent Haldane gas analysis apparatus.

The importance of registering automatically the body movements of men or animals in metabolism experiments has long been recognized, and this apparatus is provided with a unique feature for obtaining a graphic record of all body movements of the animal. The subject is placed inside of a cage, one end of which rests on a knife-edge, the other end being supported by a stout spring. Any change in the position of the center of gravity of the animal varies the tension upon the spring; by means of a pointer fastened to the end of the cage and connected to a water seal in the cover, a direct graphic record of the movements of the cage is made upon a kymograph. The importance of knowing the muscular movements of the animal and the influence of temperature upon the muscular activity are extensively discussed, two curves being shown. The apparatus was devised primarily for a study of the metabolism after the removal of the hypophysis.

(6) The increase in metabolism due to the work of typewriting. Thorne M. Carpenter. Jour. Biol. Chem., 9, p. 231. 1911.

By means of the chair calorimeter, a detailed study was made of the increase in metabolism due to the work of typewriting, which included 8 experiments with 5 subjects who were skilled operators upon the typewriter. The results of the study are given in this paper. The total metabolism as measured by the respiratory exchange and the heat elimination was determined with the subjects at rest and when typewriting, the work period following immediately the rest period. Duplicate experiments were made with 3 of the subjects. It was found that the typewriting at rates from 57 to 115 words per minute resulted in increasing the metabolism above that of rest from 30 to 70 per cent, while the increase in the energy output per 1,000 words was about 7 calories, and the increase in the carbon dioxide and the oxygen was about 2.5 grams. Considered on the basis of 1,000 strokes, there was an increase of 1.6 calories of energy and 0.57 and 0.54 gram of carbon dioxide and oxygen respectively. In the experiments in which the increase was measured by periods, it was found that there was a gradual decrease in energy expenditure per 1,000 strokes, which was most marked with those subjects whose fingers became fatigued. The variation in the increase in metabolism for the different subjects was considered to be due to the difference in individual facility and technique.

(7) Some energy factors of the urine excreted after severe muscular exercise. Harold L. Higgins and Francis G. Benedict. Amer. Jour. Physiol., 28, p. 291. 1911.

The determinations of carbon and energy in urine, always of great importance in total metabolism experiments, have become of added interest in recent years in that the relationships of the total nitrogen, carbon, and energy in the urine, *i. e.*, the carbon-nitrogen and the calorie-nitrogen ratios, have acquired a pathological significance. By a study of these ratios, a perturbed metabolism may be easily detected and much information secured with regard to its character, since under such conditions there are almost invariably present in the urine intermediate metabolic products which contain considerable amounts of carbon, and relatively small amounts, if any, of nitrogen, thus increasing the carbon-nitrogen and calorie-nitrogen ratios. The use of these ratios for detecting and studying cases of perturbed metabolism not only does away with the necessity for an elaborate estimation of amino-acids, purine derivatives, etc., but is of especial value when the volume of urine is too small to admit of tests for these products. In a study made of urines excreted immediately following an exhaustive running race, these ratios were used to find whether or not a perturbed metabolism resulted from the severe muscular exercise. Some 18 urines were studied, and the results are presented in this paper. The values for 12 out of the 18 urines were normal; the remaining 6 urines gave high ratios which were probably due to perverted protein metabolism. The method used for the determination of the heats of combustion is given in some detail, and in view of the fact that the calorie-carbon ratio is constant, the advantage is pointed out of the development of either a volumetric method or a wet process by which determinations of carbon in urine can be simply, quickly, and accurately made. The paper also includes a brief review of previous study of the carbon-nitrogen and calorie-nitrogen ratios.

(8) The heat of combustion of compounds of physiological importance. Albert G. Emery and Francis G. Benedict. Amer. Jour. Physiol., 28, p. 301. 1911.

The researches conducted at the Nutrition Laboratory on the metabolism of matter and energy in the human body brought out the desirability of more specific information regarding the heat of combustion of many organic compounds of physiological importance. Accordingly, specimens of a considerable number of these compounds were obtained with as high a degree of purity as possible, and the heats of combustion determined. For these determinations, an exceedingly exact adiabatic calorimeter was used, of which the hydrothermal equivalent had been established by burning known amounts of pure cane sugar. Determinations of the carbon were made in most instances as a check upon the purity of the specimens, using the method of Fries; and as many of the compounds contained an appreciable amount of moisture, the heat of combustion was determined on a water-free basis whenever it seemed desirable. Descriptions of the method employed and of the 26 compounds used are given in this paper, together with the heats of combustion found, which are presented on the basis of constant pressure. The results represent the average of two or more closely agreeing determinations.

(9) A comparative study of temperature fluctuations in different parts of the human body. Francis G. Benedict and Edgar P. Slack. Publication No. 155, Carnegie Institution of Washington. 1911.

By means of modern apparatus and methods, it is possible to measure with great accuracy the carbon-dioxide excretion, oxygen consumption, water vaporization, and nitrogen excretion during any given experimental period, as well as the heat eliminated by radiation, by conduction, and in the latent heat of water vaporized. The measurement of the heat production, however, is dependent upon an accurate measurement of the body temperature, and this presents serious difficulties. In any method of measurement of the body temperature thus far devised, it has been necessary to assume that the body as a whole undergoes an average change in temperature equal to the fluctuations shown by the measurement of the temperature in any one portion of the body. This assumption, however, has been based upon evidence so uncertain that a study of the simultaneous fluctuations in different parts of the body was undertaken to obtain more definite information on the subject.

In the research, the results of which are presented in this publication, a study was made of the simultaneous fluctuations in body temperature with reference to determining: (1) the best place for an accurate and constant measurement of body temperature; (2) the temperature gradient of the body; and especially (3) whether or not the temperature fluctuations occurring in the different parts of the body are uniform. The thermal-junction method was employed and a special apparatus was constructed, which consisted of electrical measuring instruments, a thermal-junction system, and a constant-temperature oven. Various forms of thermal-junction thermometers were devised for the particular localities in which the temperature was taken, and in order that small temperature fluctuations might be measured with precision, the thermal-junction system also included a second series of junctions which were placed in a constant-temperature oven. The apparatus and method are described in detail in the report of the research.

In the study made of the thermal gradient of the body, the rectum was used with men and the rectum and the vagina with a woman. The measurements were usually made with a double thermometer inserted at varying depths, the results being presented in the form of curves. These indicate that the thermal gradient between the surface of the body and a depth of about 5 cm. is quite noticeable, but that it is safe to conclude that the temperature reaches the maximum at a depth of 6 to 7 cm.

In selecting the localities for the measurement of the body temperature, a special study was made of temperature measurements in the mouth with both clinical thermometers and thermal-junction thermometers. Two curves show the results of these measurements. While no definite conclusions are drawn, the experiments appear to show that temperature observations in the mouth are liable to considerable error, and that in work requiring exact measurements even the best clinical thermometers are unsatisfactory.

In the study of the simultaneous fluctuations of body temperature, 24 experiments were made, the subjects including five men and one woman. Measurements were obtained of the temperature in the rectum, vagina, and mouth; also in various superficial cavities, such as in the closed axilla and groin, between the clasped hands, and at various surface points which could be sufficiently closed by flesh to form a temporary cavity. These results are also expressed in the form of curves. The following conclusions are drawn from this series of temperature observations:

When two thermometers were placed in one internal cavity, neither one less than 6 cm. deep, the temperature curves were parallel and approximately equal.

When two thermometers were placed in one internal cavity with the distance between them 3½ cm., the outer one being within 5 cm. of the surface of the body, the curves obtained were parallel, but not equal in value, thus indicating a temperature gradient.

Thermometers placed in the rectum and the vagina, at depths of at least 6 cm., showed curves that were parallel and approximately equal.

Thermometers in the right and left axilla gave curves that were parallel, showing approximately equal temperatures. Like results were obtained when two thermometers were placed in the groin or hand.

When the subject lay down upon a couch after the slight muscular activity of coming to the laboratory and moving about before the experiment, an initial fall of internal temperature was usually shown.

Eating, or drinking hot liquids, tended to increase the body temperature, while drinking cold water had a tendency to lower it; but exposing portions of the surface of the body apparently had no effect. Muscular exercise produced a marked increase in some experiments, although in others the effect was not noticeable.

The internal temperature of the body and of the axilla, groin, hand, arm, mouth, and under the breast showed a marked tendency toward parallelism.

The general conclusion is drawn from the research that, aside from the skin temperature, a rise or fall in temperature of the rectum or vagina is accompanied by an equal rise or fall in temperature of all other parts.

(10) The determination of the constants of the differential blood-gas apparatus. Joseph Barcroft and H. L. Higgins. Jour. of Physiol., 42, p. 512. 1911.

This paper gives a method, which is simpler than any hitherto applied, for determining the constants of the differential blood-gas apparatus described by Barcroft and Roberts (Journal of Physiology, vol. XXXIX, p. 429), these constants being necessary to interpret the readings of a determination into terms of volume of blood-gas liberated or absorbed. Instead of the chemical method of calibration hitherto applied, a physical method is used involving the application of Boyle's law. The method was devised while Mr. Higgins was working with Dr. Barcroft on blood-gas experiments in the physiological laboratory in Cambridge, England.

DEPARTMENT OF TERRESTRIAL MAGNETISM.*

L. A. BAUER, DIRECTOR.

GENERAL SUMMARY.

This report is written on board the *Carnegie,* cruising in the Indian Ocean, during the months of July and August, between Colombo, Ceylon, and the island of Mauritius. The necessary additions have been made as later returns have been received from the various field parties, so as to give a complete account of all the operations of the Department to the end of the fiscal year (October 31).

Speaking of the first object in mind, attention may be called to the large corrections on present mariner's compass charts we are finding in the Indian Ocean, and those, too, over traversed routes. For two of the most extensively used charts of the "lines of equal magnetic variation" these errors approximate, respectively, 4° and 6°, though one of the charts was issued only a year ago. With the exception of a few values found by the *Galilee* in the Pacific Ocean, these are the largest errors thus far disclosed. In the portions of the North Atlantic covered by the *Carnegie* during her present cruise, the compass-chart errors have generally been below 2°, though running at times up to 2.5°. In the South Atlantic the errors, in general, have not gone over 1°. As heretofore, the information obtained is supplied promptly to the chief hydrographic establishments issuing magnetic charts, in order to enable them to revise their charts from time to time.

The chart errors are usually systematic, *i. e.,* in the same direction for large stretches, and are often found to be largely due to erroneous secular changes allowed for in attempting to bring previously observed values up to date. Thus, for example, by comparing the *Carnegie* values of 1911 with those obtained on board the German Antarctic vessel, the *Gauss,* in 1903, it is found that the north end of the compass moved to the eastward (hence diminished west declination) at the average rate of about 11′ per year off the southeast end of Africa, whereas in the vicinity of the islands of St. Paul and New Amsterdam in the Indian Ocean (lat. 35° 16′ S., long. 74° 46′ E.) it moved to the westward (increased west declination) at the average rate of about 13′ per year. The charts would give secular changes of only about one-fourth of these amounts, so that the error of reduction in but ten years amounts almost to 2°. It is doubtless due to these large secular changes disclosed in the Indian Ocean, and especially their rapid variation with geographic position, that the large errors mentioned have crept into the charts.

These interesting facts made it desirable to alter our projected track from Colombo to Mauritius sufficiently to get data for locating the region where the secular change reverses sign; *e. g.*, from increasing to decreasing west declination. This could be done approximately with the aid of the *Gauss* observations of 1903, the publication of which fortunately came to hand just before we set sail from Colombo. Thus it was found that, in about latitude 25¼° S. and longitude 60½° E., the average secular change between 1903 and 1911 was such as to increase west declination at the average rate of about 5½′ per annum, showing that the line of no change lies somewhat to the eastward of this position.

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* Address: The Ontario, Washington, District of Columbia. Grant No. 683. $94,510 for investigation and maintenance during 1911. (For previous reports see Year Books Nos. 3-9.)

The errors in the other magnetic elements, while of less importance to the mariner, are of consequence to theoretical investigations regarding the earth's magnetism. In the magnetic dip, the errors on the present cruise have amounted at times to 4°, and in the horizontal intensity to about one-twentieth part. While some of the results derived from previous analyses of the earth's magnetic field have pointed to the possibility of large and more or less systematic chart errors, it was not suspected that they would reach the magnitude disclosed by the work of the *Galilee* and of the *Carnegie*.

The *Carnegie* has continued to keep up satisfactorily with the schedule of work laid down for her circumnavigation cruise. At the beginning of the fiscal year she was on her way from the mouth of the Amazon to Rio de Janeiro. After visiting the ports of Rio de Janeiro, Montevideo, Buenos Aires, Cape Town, Colombo, and Mauritius, she again arrived at Colombo, Ceylon, on September 10. The total length of the cruise since leaving Brooklyn, June 20, 1910, up to Colombo, September 10, 1911, or in about 1¼ year's time, is 30,400 nautical miles. This represents something more than one-third of the present cruise, which is to terminate at Brooklyn in June 1913. During this period the magnetic declination has been determined at 318 different points at sea, and the magnetic dip and the horizontal intensity at 216 places. In addition, shore observations of all the magnetic elements have been made at seven ports, intercomparisons of magnetic standards have been secured at four places, and various other investigations have been carried out.

Some further improvements have been made in the instruments and methods used on the *Carnegie,* as suggested by additional experience gained. Resolutions were passed at the meetings of the magnetic commission of the International Association of Academies, and of that of the International Meteorological Committee held in Berlin last September, showing appreciation of the accuracy achieved in the ocean results and of the magnetic work thus far completed by the Department "towards the accomplishment of the great task of a magnetic survey of the whole earth."

The *Carnegie* continues to arouse interest wherever she goes, and every possible courtesy is awarded to her and her scientific personnel at the ports of call. For details of the ocean work, reference must be made to the subsequent account. The members of Mr. Peters's party have shown commendable zeal and enthusiasm in the performance of their respective duties.

Satisfactory progress has also been made in the land work. From the details given later on it will be seen that the operations have been conducted mainly in Peru and Brazil by Mr. Stewart; in Asia Minor, Turkey, Arabia, along the shore of the Red Sea, and Greece by Mr. Sligh; in Australia by Messrs. Kidson and Webb; and in China by Dr. Edmunds. Mr. Johnston, en route to join the *Carnegie* at Cape Town, succeeded in securing magnetic results at Freetown, Sierra Leone, and at two stations in the Canary Group. The Director, on his way to meet the *Carnegie* at Colombo, Ceylon, made magnetic observations at Tau Island, of the Samoan Group, on the day of the total solar eclipse of April 28, 1911; also at Pago Pago, Tutuila; Apia, Samoa; and Colombo, Ceylon. Various opportunities have also been embraced to complete the intercomparison of our magnetic standards with those of all foreign observatories. During the past year such comparisons were secured at Vieques (Porto Rico), Pilar (Argentina), Cape Town, Apia (Samoa), Port Louis (Mauritius), Batavia (Java), Alibag (Bombay), Dehra Dun (India), Helwan (Egypt), Athens (Greece), Rome (Italy), Melbourne (Australia), and Lu-kia-pang (China).

During the Director's visit to Australian institutions, arrangements were perfected towards the early accomplishment of the general magnetic survey of Australia and outlying islands under the combined auspices of local and governmental organizations, and of the Carnegie Institution of Washington. Mr. Kidson was relieved at Colombo of ocean duty on the *Carnegie* and placed in charge of the Department's work in Australia. He has been directed to keep in touch with the local authorities and to render them every assistance possible in the initiation and execution of magnetic work. The Department has agreed to supply those in a position to coöperate effectively with the required magnetic outfits in case they can not be immediately secured otherwise.

At Melbourne the Director met the committee having charge of the scientific work of the Mawson Antarctic Expedition, and discussed with them the proposed magnetic work in the Antarctic between Cape Adare and Gaussberg and embracing the region of the magnetic south pole. It was arranged that the Department supply two outfits for magnetic-survey work, and have Mr. Kidson give the necessary training to the observers. In order to put this plan into immediate execution, as the expedition expects to leave Melbourne in November of this year, Mr. E. N. Webb, associate in Engineering, Canterbury College, Christchurch, New Zealand, was given a temporary appointment as magnetic observer until November 1, and assigned to assist Mr. Kidson. Thereafter he will enter the employ of the expedition.

From the statement under "Office work" it will be seen that the office reductions have kept pace with the field work, and that the manuscript of the first volume of "Magnetic Results," containing the results of the ocean and land work to the end of 1910, will be ready to go to press next year. In addition, several special investigations have been made, both with respect to instrumental and to theoretical matters. Besides the usual repair work in the shop, two new types of magnetometers, one of which is of a very portable character designed for difficult land expedition and capable of measuring all the magnetic elements, have been constructed. An improved form of our "deflector" has also been made for measuring declination and horizontal intensity at sea. I must express my obligation to Mr. Fleming for the efficiency here obtained. During my absence in the field he was placed in sole charge of the office work. He refers to the effective assistance received from various members of the office staff.

The President, in his report for 1910, speaks of the "utilitarian results," besides the benefits to science, which "may come from a deeper knowledge of the earth's magnetism and its cosmic connections." The utilitarian results to navigation at present accruing from the revealed chart errors are immediately recognized. Some mariners, to be sure, at first thought our work "ultra-scientific," but it was soon found that our observations disclosed errors in the charts frequently exceeding considerably their assumed accuracy of the "lines of equal magnetic variation."

To reap full advantage of the observational work now in progress, it has been found advisable to undertake immediately various preliminary investigations pertaining to the theory of the earth's magnetism and of its variations. These theoretical researches, of which four have been completed thus far, and a fifth is in progress, are being published in the journal "Terrestrial Magnetism and Atmospheric Electricity," the form chosen being such as to give other magneticians an opportunity to participate in helpful discussions of more or less mooted questions of theory. Several lines of inquiry have been revealed, along which further research might be profitably conducted. An impetus has been given for stimulating interest in securing greater accuracy than has been generally attained hitherto in the time-scalings of important events recorded on magnetograms. Various magneticians are, in consequence, at present engaged in a renewed study of the magnetic perturbations, especially with reference to the question as to whether even the most sudden of these phenomena occur at the same measurable instant of time all over the globe.

DETAILS OF MAGNETIC WORK, NOVEMBER 1, 1910, TO OCTOBER 31, 1911.

LAND WORK.

Africa.—Upon the completion of his work in Turkey and Arabia, Magnetic Observer W. H. Sligh made magnetic observations along the shore of the Red Sea at four stations, occupied the secular variation station at Suez, and carried out intercomparison observations at Helwan Magnetic Observatory.

Magnetic Observer H. F. Johnston, en route to join the *Carnegie* at Cape Town, observed the magnetic elements at the secular variation station at Free Town, Sierra Leone, and at two stations in the Canary group.

Asia.—The work in China during the year has been confined to that of Magnetic Observer C. K. Edmunds, who occupied about fifteen stations in the provinces of Kwangtung, Kwangsi, Kiangsi, Anhwei, and Kiangsu; several of these were secular variation stations. He has also carried out intercomparison observations at the Hongkong and Lu-kia-pang (near Shanghai) observatories and returned to Canton in the latter part of September. He initiated, October 1, a campaign, which it is planned will further extend the magnetic survey of China into the provinces of Kwangsi and Yunnan, and into Indo-China. At the end of October he had occupied about ten stations of this work. Dr. Edmunds is accompanied by Observer Ngaan Yen Kwong.

Magnetic Observer W. H. Sligh at the end of the last fiscal year was engaged in work in Asia Minor. This he continued, completing observations at nineteen stations in the vilayets of Erzerum, Bitlis, Van, Diarbekir, Mosul, and Bagdad. He also occupied two stations in India, one of these being for intercomparison of observatory standards at the Bombay Observatory (Alibag), and four stations in Arabia, one of which was a secular variation station. Concluding his work at Helwan, Egypt, he then, just before taking up his work in Turkey in Europe, determined the magnetic elements at the secular variation station at Constantinople.

Australasia.—Magnetic Observer E. Kidson was relieved from sea duty on board the *Carnegie* in June and proceeded immediately to take charge of magnetic-survey work in Australia. At the end of the year he had secured observations at about thirty-five stations in Victoria, South Australia, and New South Wales. These include observatory comparisons at Melbourne and reoccupations suitable for secular variation data.

Europe.—Magnetic Observer W. H. Sligh occupied nine stations in Turkey in Europe and four stations in Greece, securing valuable secular variation data. At the end of the fiscal year he was in Italy securing instrumental comparisons with the outfit of Prof. Luigi Palazzo. Of the stations in Greece, one was at Athens, where intercomparisons between the standards of the National Observatory and those of the Department were carried out.

Polynesia.—In the course of his inspection work the Director took advantage of an occasion presented for obtaining special magnetic observations at Tau Island, of the Samoan group, on April 28, 1911; photographs of the sun during the eclipse were also obtained with an eclipse camera supplied through the courtesy of Dr. C. G. Abbot, of the Smithsonian Institution. Through the courtesy of the governor of Tutuila (American Samoa), Commander Crose, U. S. Navy, the Director was transported with his outfit on the U. S. cruiser *Annapolis* from Pago Pago to Tau Island and return, and also back to Apia, Samoa. Furthermore, several of Commander Crose's best naval officers and men were assigned to the expedition. Mention should also be made of the valuable aid rendered in the furtherance of the work by the acting governor of German Samoa, Dr. Erich Schultz, and by the American consul, Hon. Mason Mitchell, stationed at Apia. The native Samoans likewise rendered every possible assistance. It was these various courtesies which made the expedition possible. The Director, on return from the eclipse trip in May, made magnetic observations at Pago Pago, Tutuila, and at the magnetic observatory at Apia, Samoa.

South America.—Magnetic Observer C. C. Stewart has continued his work in South America. The progress of this work was somewhat retarded by the unfortunate destruction by fire of the launch *El Imán* while in port at Iquitos, Peru, on January 15. It proving impracticable to replace the launch, he then continued the work with the aid of such local means of travel as were found available. He occupied twenty-two stations in Peru and Brazil and completed the line of magnetic survey for practically the whole length of the Amazon. Besides establishing several secular variation stations, he tied up his work with that of the *Carnegie* at Pinheiro. Mr. Stewart returned to the Office in September and is at present recuperating from fever contracted in the course of the work.

Miscellaneous.—In connection with the operations of the *Carnegie,* land stations have been established at Pinheiro (near Para) and Rio de Janeiro, Brazil; at Pilar, Córdoba, where intercomparisons were obtained with the standards of the magnetic observatory of the Argentine Republic; at Cape Town, South Africa; at Colombo, Ceylon; at Port Louis, Mauritius, where intercomparisons were obtained with the magnetic standards of the Royal Alfred Observatory; and at Buitenzorg, Batavia, Java, where the *Carnegie's* instruments were compared with the standards of the Royal Meteorological and Magnetic Observatory.

INSPECTION WORK.

The Director left Washington on March 16 in order to make a trip of inspection of the land and ocean work and to confer with the heads of various magnetic organizations in Australasia and Asia respecting continuation or inauguration of magnetic surveys under their charge. He left Vancouver, British Columbia, on March 24, going via Hawaii and Fiji to Samoa, where he obtained eclipse magnetic observations at Tau Island. He made magnetic observations at Pago Pago and Apia, as elsewhere stated, and proceeded thence to Auckland, New Zealand; Christchurch, New Zealand, and Sydney and Melbourne, Australia, visiting the magnetic observatories at Christchurch and Melbourne. At Sydney and at Melbourne he met the members of the committee having charge of the scientific work of the Australasian Antarctic Expedition, under the leadership of Dr. Douglas Mawson, and made the necessary arrangements with them regarding coöperation of the Department with the expedition in proposed magnetic-survey work in the Antarctic. From Melbourne he went to Adelaide, thence to Fremantle and Perth, and then directly to Colombo, Ceylon, arriving there June 21. At the various places visited in Australia the interest of local organizations was enlisted and arrangements were perfected for the inauguration of a magnetic survey of Australia (one of the largest land areas remaining to be explored from this standpoint) under the joint auspices of the Department and of the local organizations. As elsewhere stated, Magnetic Observer Kidson has been placed in charge of the Department's work.

At Colombo the Director made an examination of the ocean results and secured comparisons between the magnetic standards carried by him and those of the *Carnegie*. From Colombo he proceeded with the *Carnegie* to Port Louis, Mauritius Island, and thence with her on the return to Colombo, inspecting the ocean work and making various tests. The party arrived the second time at Colombo September 10. After supplying the commander, Mr. Peters, with such additional instructions as were necessary for the continuation of the work, he left the party September 11, for Bombay, Dehra Dun, and Calcutta, India. He arrived at Batavia on October 23 and left for Hongkong, China, October 28, after having given final instructions for the work of the *Carnegie*. At the close of the fiscal year the Director was en route.

OCEAN WORK.

At the end of the last fiscal year the *Carnegie* was en route between Pará and Rio de Janeiro, Brazil. She arrived at the latter port on December 2, 1910, the voyage having been made under very favorable observing conditions. Intercomparisons of barometer standards were carried out at the Rio de Janeiro Observatory. Upon the completion of the usual harbor intercomparisons of land and ship instruments, and swing observations on December 23 and 24, the party sailed on December 29 for Montevideo, Uruguay, and Buenos Aires, Argentine Republic.

No land observations were made at Montevideo, at which place the *Carnegie* arrived on January 14, whence she proceeded, after a short delay by storm, to Buenos Aires, arriving there January 18, 1911. The observing conditions between Rio de Janeiro and Buenos Aires were very good and numerous observations were obtained. The comparisons of ship and land instruments, as well as the intercomparisons of the Argentine magnetic standards and those of the Department, were carried out at the magnetic observatory of the Meteorological Service of the Argentine Republic at Pilar, Córdoba. Comparisons of barometer standards were also made at the office of the Meteorological Service in Buenos Aires.

The *Carnegie* sailed from Buenos Aires on February 14; but owing to adverse winds and tidal conditions, together with the loss of an anchor, subsequently recovered, did not get to sea from the river until the 21st. Owing to this delay and to foggy weather in the vicinity of Tristan da Cunha, it was found impracticable to stop at this island, as had been planned, so that practically a great-circle course was followed between Buenos Aires and Cape Town. This portion of the cruise was very successful and many data were secured, despite the foggy conditions prevailing during a part of the time. Cape Town was reached March 20. Intercomparisons of the land and sea instruments, as well as comparisons between the magnetic outfits of Professors J. C. Beattie and J. T. Morrison, were secured at Valkenberg, near Cape Town. Barometer comparisons were made with the standards of the Royal Observatory, Cape of Good Hope. At Cape Town Dr. H. M. W. Edmonds, Surgeon and Magnetician, and H. F. Johnston, Magnetic Observer, joined the vessel. Dr. C. C. Craft, who had been Surgeon and Magnetic Observer on board the *Carnegie* since the initiation of her work, was relieved of sea duty at Cape Town to return to the office, owing to the very poor condition of his eyes.

Upon the completion of the intercomparisons at Cape Town, the *Carnegie* left for Colombo on April 26, arriving there June 7, 1911. The course from Cape Town was made for St. Paul Island, and thence directly for Colombo. This passage of the cruise was accomplished with cloudy weather and heavy sea during the westerly course, and under fine conditions during the northerly course. Observations were made nearly every day. At Colombo the Director met the vessel for the purpose of a general inspection and for consultation with the commander as to the details of the work, and for discussion regarding such alterations as might be deemed advisable for further improvement. Magnetic Observer E. Kidson, who had been observer on board the *Carnegie* since the initiation of her work, was relieved of sea duty at Colombo and proceeded at once to Australia to take up there the magnetic-survey work, as elsewhere stated.

Having completed the intercomparisons at Colombo of the land and sea instruments and the barometric standards at the meteorological observatory, the *Carnegie* set sail on July 6, 1911, for Port Louis, Mauritius Island, with the Director aboard, arriving there August 5 on schedule time. This portion of the cruise was made, with the exception of a few days, under very favorable conditions. Valuable observations (63 determinations), both with regard to the distribution of the magnetic elements and their secular changes, were secured, the course to Mauritius being deflected to the southward in order to reach the track of the *Gauss* (see general summary). On this portion also the track of the *Carnegie* northward to Colombo from St. Paul Island was crossed, and thus valuable opportunity was afforded for testing the accuracy of her work as well as chart errors found. The results of these tests were found very satisfactory. Intercomparisons of land and sea instruments, as well as a valuable intercomparison of the standards of the Department and those of the Royal Alfred Observatory, were secured.

The land work being completed, the *Carnegie* left Port Louis, bound for Batavia *via* Colombo, on August 16, 1911, the Director continuing with the vessel. A short stop was made at Colombo, during September 10 to 15, and there the Director left the party to visit magnetic organizations and observatories in India, the East Indies, and China. Excellent conditions prevailed between Mauritius and Colombo and 61 magnetic determinations were made. After a 43 days' cruise from Colombo, during which the desired observations were secured, Batavia was reached on October 27, 1911. The course from Mauritius carried the party first to the westward of the Seychelles Islands into the western part of the Arabian Sea, where the agonic was located by two widely separated crossings, and across the tracks of the principal steamship lines, thence back to Colombo, and from there to Batavia. Intercomparisons of the sea and land instruments, as well as valuable intercomparisons of the standards of the Department and those of the Royal Meteorological and Magnetic Observatory, were secured at Batavia. At the end of the fiscal year these intercomparisons were still under way. The Director again met the vessel at Batavia to give final instructions for the continuation of her cruise under Mr. Peters's command.

At each port of call the party has received most cordial assistance. In particular may be mentioned Mr. Hartnell, observer-in-charge of the U. S. Coast and Geodetic Survey Magnetic Observatory at Vieques, Porto Rico; Dr. H. Morize, director of the Observatorio Nacional, and Capt. Radler de Aquino, at Rio de Janeiro; Dr. Walter G. Davis, director of the Meteorological Service of the Argentine Republic, and his various assistants at the observatory at Pilar; the government officials of the Department of Agriculture of the Argentine Republic; Drs. Beattie and Dodds, of Cape Town; Dr. Hough, director of the Royal Observatory, Cape of Good Hope; Dr. Barnard, assistant surveyor-general of Ceylon, and his assistant, Mr. Bamford, in charge of the observatory at Colombo; Mr. A. Walter, director of the Royal Alfred Observatory at Mauritius; and Dr. W. van Bemmeln at Batavia. The various official representatives of the United States Government have also been of invaluable assistance at the various ports of call, and have greatly facilitated the work.

Atmospheric electricity observations have been conducted on board the *Carnegie,* as opportunity afforded, by Messrs. Kidson and Johnston, Magnetic Observers. Atmospheric-pressure observations have been carried out and various improvements in the method of observations effected. Observations for atmospheric-refraction effects at sea have also been made, as was possible during the cruise.

The personnel of the *Carnegie* during the year has been as follows:

Scientific staff: L. A. Bauer, Director; W. J. Peters, commander; C. C. Craft, surgeon and magnetic observer to April 1911; H. M. W. Edmonds, surgeon and magnetician from March 1911; E. Kidson, magnetic observer to June 1911; H. D. Frary, magnetic observer; H. F. Johnson, magnetic observer from March 1911; C. R. Carroll, meteorological observer and clerk to September 1911.

Sailing staff: F. S. McMurray, first watch officer; M. Clausen, second watch officer; A. Jorgensen, third watch officer to January 1911; E. W. Jansson, third watch officer from February 1911; M. G. R. Savary, engineer to February 1911; D. Bam, engineer since April 1911; 1 mechanic, 8 seamen, 2 cooks, 2 cabin boys.

OFFICE WORK.

The manuscript giving the magnetic results obtained in the land observations since the inauguration of the work of the Department and through December 31, 1910, and for the land stations occupied by the *Galilee* and the *Carnegie* parties through April 1911 will be completed, it is expected, in time to turn over to the printer at the end of the calendar year. The manuscript for the publication, giving the magnetic results of the ocean observations obtained during the various cruises of both the *Galilee* and the *Carnegie,* including all sea work by the Department through April 26, 1911, will also be completed and ready for the printer at the same time. Considerable attention has been given to the further discussion of differences between magnetic standards and the possible establishment of international magnetic standards; the results of all intercomparisons obtained by the Department through March 1911 have been published in the June and September issues of the journal "Terrestrial Magnetism and Atmospheric Electricity." Descriptions of the two new types of magnetometers designed and constructed by the Department and of the improved deflector for sea work have been prepared and published in the same journal. The Director has also continued his series of papers in the same periodical on "The physical theory of the earth's magnetic and electric phenomena."

The constants and corrections to the provisional International Magnetic Standards of the Department have been determined or redetermined for 8 magnetometers and 6 dip circles. These standardizations have been made by the method of simultaneous comparisons with the standard instruments. The reductions of the field observations have been kept up to date. General and specific instructions for the prosecution of field and ocean work have been prepared as necessary.

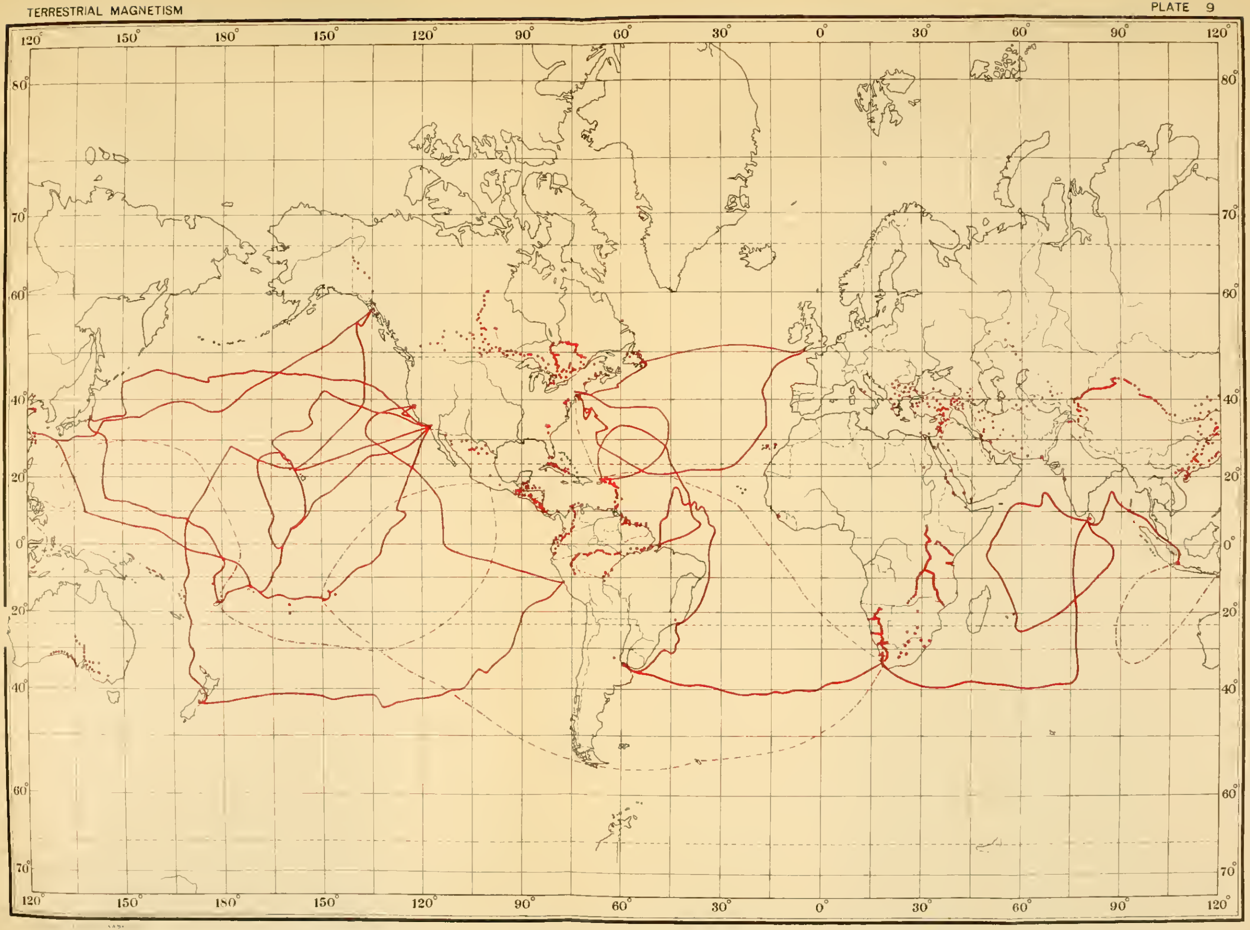
The compilation of past magnetic work, the indexing of current literature, and abstracting of publications of a special interest have been continued. Requisitions for data and information have been numerous and varied and responses have been made in such detail as has been possible.

SHOP WORK.

Theodolite-magnetometers 16, 17, and 18 have been completed during the years; these are of the light, portable type. Four universal magnetometers of the 1910 type (No. 14) are well under way. Some progress has also been made with the design of a compact and portable earth-inductor-magnetometer. The improved type of deflector used on board the *Galilee* and the *Carnegie* was completed and forwarded to the *Carnegie* at Cape Town, April 1911. The construction of accessory instruments and the overhauling and repairing of field outfits have been carried out as necessary.

PERSONNEL.

The personnel of the office force during the year has been as follows: L. A. Bauer, Director; J. A. Fleming, magnetician in charge of office and shop; H. W. Fisk, magnetician; J. P. Ault, magnetician; H. M. W. Edmonds, magnetic observer from January 1 to February 14, 1911; C. C. Craft, magnetic observer during part of May and June 1911; H. F. Johnston, magnetic observer to January 30, 1911; J. H. Millsaps, bookkeeper and stenographer; Emma L. Beehler, stenographer; A. Widmer, chief mechanician; E. Skonberg, mechanician; B. Brauner, messenger to September 15, 1911.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THE MAGNETIC WORK OF THE DEPARTMENT OF TERRESTRIAL MAGNETISM, 1905-11

Projected cruise of the Carnegie

November 1911 to June 1913 -.-.-.-.-.-.-.- -.-.-.- -.-

ARCHEOLOGY.

American School of Classical Studies at Athens. James R. Wheeler, Chairman of the Managing Committee, Columbia University, New York, N. Y. (*a*) Grant No. 619. *Maintenance of a fellowship in architecture at Athens,* $1,200. (*b*) Grant No. 661. *Special fellowship awarded to Allan Chester Johnson,* $1,200. (For previous reports see Year Books Nos. 4–9.) $2,400

(*a*) *Fellowship in Architecture:*

Mr. William B. Dinsmoor, the Fellow in Architecture, has continued his work on the Propylæa at Athens. This year he has devoted much time to the building inscription and has succeeded in bringing together so many unrecognized and unknown fragments of the inscription that a new publication of this important document has become imperative. The building accounts of the Parthenon are closely related to this inscription, and in his study of these Mr. Dinsmoor has added much that is important for the study of this temple. Thus a good deal of material has been gathered for the proposed publication on the Propylæa. Mr. Dinsmoor has completed, also, some interesting studies of remains at Delphi, which are soon to appear in the *Bulletin de correspondance hellénique.* These are concerned generally with the identification and dates of the Treasuries, and particularly with the architectural features and sculptural decoration of the Siphnian and Cnidian Treasuries. These studies are of high merit.

(*b*) *Special fellowship:*

Dr. Johnson was occupied at the beginning of the year with a comparative study of certain syntactical points in the Attic psephismata before 300 B. C., and in the orators Isæus and Isocrates. This will be published for the Johns Hopkins University. Later Dr. Johnson resumed work on the inscriptions which he found last year. This led to a study of the archons of the third century B. C. through the fixing of a new date (232/1) for the establishment of the tribe Ptolemais at Athens. The whole result has been a noteworthy contribution to the history of the Macedonian period at Athens.

The American School of Classical Studies in Rome. Andrew F. West, Chairman of Managing Committee, Princeton University, Princeton, New Jersey. Grant No. 702. *Continuation of investigations in the field of Roman archeology.* (For previous reports see Year Books Nos. 4–9.) $2,000

Dr. Elias A. Loew was reappointed for the current academic year 1910–11. His task for the last five years has been a study of the script of Beneventum; he has worked steadily at a monograph on the subject, and has also, from time to time, published minor results. He submitted to the Munich Academy of Science a monograph "Studia Palægraphica," a contribution to the history of early Latin Minuscule and to the dating of Visigothic MSS.; this was published in the Sitzungsberichte der k. bayerischen Akademie der Wissenschaft, November 1910. Dr. Loew has also contributed to the Berliner philologische Wochenschrift (July 22, 1911) an article on "The Naples MS. of Festus; Its Home and Date." During the year the great monograph on Beneventum Script, which has been the primary object of all his activity, has made steady progress, and largely through the interest of the Vatican library its publication has been undertaken. It consists of two parts:

(*a*) *Scriptura Beneventana:* a series of about 100 photographic reproductions of examples of the Beneventan Script, with explanatory text, produced in the style of the publication of the "Society of Dilettanti."

(*b*) *The Beneventan Script:* a history of the origin, development, and influence of this famous school of writing.

The existence of these two works is almost entirely owing to the generosity of the Carnegie Institution of Washington.

Miss Dora Johnson, who has been previously a member of the school, has pursued her investigation of the MSS. of the letters of Pliny. During the year she worked in the libraries of Oxford, London, Rouen, Paris, Turin, Venice, Rome, Naples, Florence, Pistoia, Cesena, Modena, Parma, and Milan. She studied and inspected 125 MSS. of the letters. An annotated list of all the known MSS. of the letters has been prepared for publication.

Müller, W. Max, Philadelphia, Pennsylvania. Grant No. 646. *Continuation of archeological research in Egypt.* (For previous reports see Year Books Nos. 3, 5, 6, 9.) $2,000

Professor Müller worked in Egypt during the summer and fall of 1910, beginning with Cairo. In upper Egypt his principal work was on the doomed Island of Philæ, where he collected the demotic inscriptions. He found between two hundred and three hundred of these engraved or written with black or red ink, or only sketched with reddle on the walls of the temples, although the Nile had destroyed much which might have been saved if an effort could have been made two years previously. The study of this rich material will occupy considerable time. The Egyptian government aided these researches in every way.

After concluding at Philæ, work was begun at Thebes, where new and very important results were obtained, especially on the western side of the ancient capital of Egypt, in the necropolis. The temple of Karnak also yielded some excellent material. Some time was well spent in studies in Sudanese negro languages, and material obtained which will be printed in the future.

Van Deman, Esther B., Rome, Italy. Grant No. 687. *Research Associate in Roman Archeology.* (For previous report see Year Book No. 9.) $1,200

During the months of September and October 1910 regular work was continued on the general classification, on the basis of materials and methods of construction, of the more important ancient monuments inside the city of Rome. The month of November was mainly devoted to the determination of the various periods of construction to be found in the Colosseum. This preliminary study revealed the presence of at least four distinct types of construction, belonging to as many periods, making clear also the original unity in structure of the three lower stories and the probable later construction, in wood, of the fourth story; also the extent of the fire in 217 A. D. and the restoration resulting from it, as well as the character and extent of the later restorations. In connection with this investigation, many remains in the vicinity were identified as of the Flavian period, the most important of which are the arches of the aqueduct between the Cælian and the Palatine hills, usually assigned to the period of Septimus Severus.

In the Forum the history of a number of the monuments, as shown by their construction, has been wholly or in great part completed. Among these are the two Basilicas, the Regia, the temple of Castor, and the so-called temple of Augustus. The most interesting results, however, have been the discovery of the extensive remains still left, though unrecognized, of the Forum of the period of Augustus, and the location of several monuments, hitherto unlocated; the most important of these is the Porticus of Lucius and Gaius, built by Augustus.

The recent publication of a new plan of the center of the ancient city, made by the School of Engineers of Rome, has rendered easy the resumption of the study of the levels on the Palatine and in certain other parts of the city. The work on the Palatine so far has led to the assignment of the greater part of the existing remains, except those on the southwest corner of the hill, to the period of Domitian.

The months from December 1910 to April 1911, inclusive, were spent in America. During that time conferences were held with a number of the leading authorities on modern brick-making and concrete construction, as well as with many workers along allied lines. Two papers on the methods of investigation used in the work in Rome were presented at the annual meeting of the Archæological Institute of America, at Providence, Rhode Island. Sixteen formal and a number of informal lectures were delivered in various universities and colleges. Among these institutions were the universities of Chicago, Johns Hopkins, Michigan, Oberlin, Ohio, and Pennsylvania, and the colleges of Holyoke, Smith, Swarthmore, and Wells.

The remaining months of the year have been spent for the most part in the regular work in Rome and the immediate vicinity.

ASTRONOMY.

Schlesinger, Frank, Allegheny, Pennsylvania. Grant No. 422. *Completion of parallax computations begun under direction of George E. Hale.* (For previous reports see Year Books Nos. 6, 7.) $300

The computations made under this grant were completed in 1908, in which year the principal results were briefly communicated to the Astronomical and Astrophysical Society of America at its annual meeting at Put-in-Bay, Ohio. Shortly afterwards the derived parallaxes were made generally available to astronomers through the compilation of stellar parallaxes made by Kapteyn and Weermsa (Groningen Publications of the Astronomical Laboratory, No. 24).

Owing to the pressure of more immediate duties, time to prepare this work for detailed publication was not forthcoming until last winter. With the approval of the President of the Carnegie Institution of Washington, the Astrophysical Journal was selected as the medium of publication. Seven papers appeared in consecutive numbers of this Journal (vol. XXXII, No. 5; vol. XXXIII, Nos. 1–5, and vol. XXXIV, No. 1), of which 400 reprints (in book form) have been secured, and have been distributed among the leading observatories and astronomers. These reprints bear the title "Photographic Determinations of Stellar Parallax made with the Yerkes Refractor, under the auspices of the Carnegie Institution of Washington, D. C."

The chief distinctive features of this work are (1) the sacrifice of a reduction in accidental errors in order to exclude systematic error as far as possible; (2) the elimination of guiding error by means of a rotating disk of adjustable aperture, and (3) the use of a very short and entirely rigorous method of reduction.

In spite of the sacrifice in the matter of accidental error, it appears that with a telescope of this size and character, the number of stellar parallaxes that can be determined per annum with a probable error of $\pm 0.''013$ will (in the long run) be about equal to the number of clear nights available for this work.

BIBLIOGRAPHY.

Fletcher, Robert, Army Medical Museum, Washington, District of Columbia. Grant No. 711. *Preparation and publication of the Index Medicus.* (For previous reports see Year Books Nos. 2–9.) $12,500

The volume of the Index Medicus for 1911 has been issued in its usual monthly numbers to the present time. Some important additional subdivisions have been introduced. Two especially interesting titles may be mentioned, namely, Anaphylaxis and "606." The latter, more generally known as Ehrlich's remedy for syphilis, or as Salvarsan, has provoked a large amount of discussion. The general subject of syphilis in accordance with present views has been placed under "Parasitic diseases."

CHEMISTRY.

Acree, S. F., Johns Hopkins University, Baltimore, Maryland. Grant No. 690. *Continuation of the study of tautomerism and catalysis.* (For previous reports see Year Books Nos. 4–9.) $1,500

Work on tautomerism and catalysis has been continued with the cooperation of Dr. B. B. Turner, Dr. H. C. Robertson, jr., Dr. E. K. Marshall, jr., Dr. N. E. Loomis, Dr. E. P. Doetsch, Miss J. P. Harrison, Mr. E. W. Esslinger, and Mr. J. Chandler.

During the year the work on catalysis has been greatly benefited by the work of Dr. Robertson, Dr. Marshall, and Miss Harrison. They have measured accurately the ionization of various ethylates and phenolates and determined the corresponding reaction velocities of these salts with alkyl halides. In all cases the reaction velocity has been found proportional to the product of the concentration of the ions and the K_{ion} increased by the product of the concentration of the molecules and K_{mol}. Dr. Marshall has further found that sodium ethylate catalyzes the reversible reaction involving the addition of alcohols to nitriles. Here again the reaction velocity is a function of the concentration of the ethylate ions and sodium ethylate molecules as expressed above, the values of K_{ion} and K_{mol} varying in different reactions, but remaining constant for all dilutions in the same reaction.

Messrs. Doetsch, Chandler, and Esslinger have presented very valuable conclusions as a result of their studies of the tautomeric relations of the urazoles.

Dr. N. E. Loomis has made a very exact study of the hydrogen electrode, the calomel electrode, and of contact potential. He finds that 4.12 N potassium chloride solutions nearly completely annul the contact potential of systems containing hydrochloric acid and potassium chloride. He has defined the value of the hydrogen-calomel cell and found a method for measuring the percentage of hydrolysis of solutions of aniline hydrochloride. This work is being continued by Dr. C. N. Myers.

The following papers have appeared during the year or are now in press:

On the reaction of iodoacetonitrile with silver nitrate. By S. K. Loy and S. F. Acree. American Chemical Journal, 45, pp. 224–239.

In this article Dr. Loy has shown by conductivity methods that silver nitrate does not combine in water or alcohol with iodoacetonitrile to any appreciable extent. Although this double compound, $AgNO_3 . ICH_2CN$, precipitates out when concentrated solutions of the two components are brought together, this is true because of its insolubility and not on account of any great concentration of the substance in the solution at any moment.

The hydrolysis of acid amides. By E. Emmet Reid. American Chemical Journal, 45, pp. 327–343.

Dr. Reid has made some very accurate measurements of the rate of hydrolysis of amides by alkalies which harmonize with our theory that the alkali forms a salt with the amide.

A study of the hydrogen electrode, the calomel electrode, and of contact potential. By N. E. Loomis and S. F. Acree. American Chemical Journal, December 1911.

In this article are discussed the value of the electromotive force of the calomel electrode and the hydrogen electrode, which have been defined to within 0.1 millivolt. It is shown that a 4.12 N solution of potassium chloride nearly eliminates the contact potential between solutions of hydrochloric acid and potassium chloride.

The application of the hydrogen electrode to the measurement of the hydrolysis of aniline hydrochloride and the ionization of acetic acid in the presence of neutral salts. By N. E. Loomis and S. F. Acree. Amer. Chem. Journal, December 1911.

Dr. Loomis has obtained some very concordant results in measuring the concentration of the hydrogen ions resulting from the hydrolysis of aniline hydrochloride. This method promises to be of very general application.

Difficulties in the application of the hydrogen electrode to the measurement of the concentration of hydrogen ions in the presence of organic compounds. By L. J. Desha and S. F. Acree. American Chemical Journal, December 1911.

Dr. Desha has studied the influence of organic compounds on the potential of the hydrogen electrode, and has learned that although some substances do not change the potential of the hydrogen electrode, others do very materially. Conclusions must therefore be drawn very conservatively and only after careful study.

Bancroft, W. D., Cornell University, Ithaca, New York. Grant No. 684. *Systematic study of alloys.* (For previous reports see Year Books Nos. 2–9.) $1,500

There has been very little progress made on the iron-carbon diagram. During the annealing at 1000° some of the carbon burned out of the alloys, and this work will have to be done over again with increased precautions. The recording differential thermometer has proved an absolute failure and has been abandoned for the present. Through the courtesy of the Director of the Geophysical Laboratory, Dr. Day, the temperature measurements are now being carried on in that laboratory.

Experiments on the tensile strength of electrolytic copper have given very satisfactory results. Good deposits of copper have been obtained from an acidified copper sulphate solution up to a current density of 4,000 amperes per square foot, and there is no reason to suppose that this limit can not be pushed higher if desired. By keeping down the temperature of the electrolyte the equivalent of a hard-drawn copper has been obtained electrolytically, the tensile strength being 68,000 pounds per square inch. At temperatures of 75° a ductile copper is obtained which is equivalent to annealed copper.

Corresponding results with electrolytic bronze have not yet been obtained, apparently because the tin dissolves at the anode in a colloidal form which is not available. Electrolytic brass from a cyanide solution is brittle; the reason for this has not yet been established definitely.

The electrolytic corrosion of brass has been determined in chloride and sulphate solutions, and we are now determining the tensile strength of cast brass.

Baxter, Gregory P., Harvard University, Cambridge, Massachusetts. Grant No. 691. *Determination of atomic weights.* (For previous reports see Year Books Nos. 3–9.) $1,000

With the assistance of the above grant the following researches were carried on under Professor Baxter's direction:

The analysis of phosphorus tribromide has been completed by Dr. C. J. Moore (for previous reports on this research see Year Books Nos. 7, 8, and 9). The preparation of this substance by the union of dry phosphorus and bromine in a vacuum and subsequent fractional distillation, and the analysis of the separate fractions for bromine by precipitation, as silver bromide, have already been described in Year Book No. 9. Three series of samples were collected by fractional distillation of three different preparations. Of these the third was distilled over metallic silver. In the following tables of results a higher number indicates an earlier fraction, while the lowest number represents essentially residual material. The atomic weight of silver is assumed to be 107.88.

Number of fraction.	Ratio, $PBr_8 : 3Ag$.	Atomic weight of phosphorus.	Ratio, $PBr_3 : 3AgBr$.	Atomic weight of phosphorus.
SERIES I.				
1	0.836668	31.031	0.480633	31.035
2	0.836657	31.028	0.480641	31.039
3	0.836676	31.034	0.480624	31.031
4	0.836669	31.031	0.480636	31.036
5	0.836665	31.030	0.480632	31.034
8	0.836648	31.025	....	....
9	0.836648	31.025	0.480615	31.025
10	0.836666	31.030	0.480623	31.029
Average	0.836660	31.031	0.480629	31.033
SERIES II.				
1	0.836628	31.018	0.480631	31.034
2	0.836648	31.025	0.480631	31.034
5	0.836644	31.024	0.480624	31.030
6	0.836653	31.026	....	....
7	0.836644	31.023	0.480629	31.032
8	0.836625	31.018	0.480623	31.029
Average	0.836640	31.022	0.480628	31.032
SERIES III.				
1	0.836671	31.032	0.480643	31.040
3	0.836636	31.021	0.480604	31.019
4	0.836611	31.013	0.480610	31.022
6	0.836637	31.021	0.480603	31.018
8	0.836644	31.023	0.480594	31.013
Average	0.836640	31.022	0.480611	31.022

The different fractions of the same preparation in every case yield results so nearly identical that it seems reasonably certain on the one hand that the slight excess of bromine used in the synthesis of the tribromide was eliminated during the early stages of the fractional distillation, and on the other hand that there was no appreciable decomposition of the tribromide even in contact with metallic silver. Furthermore, the averages of the three series agree as well as could be expected. If all the results are given equal weight the mean value of the atomic weight of phosphorus is 31.027, a result essentially that obtained previously by Baxter and Jones by the analysis of silver phosphate, 31.03. This research will soon be published in the Proceedings of the American Academy of Arts and Sciences. Dr. Moore has also begun the preparation and analysis of phosphorus trichloride.

In order to explain the slight discrepancy between the value for the atomic weight of iron previously found by Richards and Baxter by the reduction of ferric oxide, 55.88, and that found by Baxter, Thorvaldson, and Cobb by the analysis of ferrous bromide, 55.84 (see Year Book No. 9), ferric oxide was subjected to new analyses by reduction in hydrogen, in the hope that by the use of modern quartz apparatus more satisfactory results could be obtained. This hope was fully realized. Very carefully prepared ferric oxide, upon reduction for a prolonged period at about 1100° in a quartz tube, has yielded the results 55.839, 55.844, 55.851, 55.850, 55.846, 55.843, 55.848; average 55.846. This investigation is being continued to include the examination of meteoric material.

The investigation upon the atomic weight of arsenic has been continued in two ways. The comparison of arsenic trioxide with iodine, commenced last year by Mr. G. W. Harris (see Year Book No. 9), has been extended by him to include the examination of arsenic trioxide which has been sublimed in a vacuum; while Mr. P. C. Voter has begun the comparison of arsenic trioxide with iodine pentoxide. Although no final results have been obtained in either case, preliminary experiments indicate that both methods yield the same value for arsenic that was obtained by Baxter and Coffin by the analysis of silver arsenate, 74.96.

In addition, the atomic weights of silver, iodine, and neodymium are still under investigation and a new research upon the atomic weight of praseodymium has been begun.

Jones, Harry C., Johns Hopkins University, Baltimore, Maryland. Grant No. 688. *Investigations on the absorption spectra of solutions.* (For previous reports see Year Books Nos. 2–9.) $1,200

The work on the absorption spectra of solutions, carried out during the past year, had to do with three general problems:

First, the absorption spectra of comparatively rare substances have been mapped. These include salts of neodymium in a number of non-aqueous solvents, such as propyl, isopropyl, butyl, and isobutyl alcohols; ether, acetone, esters, and formamide. Certain uranyl and uranous salts were also investigated in these non-aqueous solvents. It was always found that the absorption bands widen and become more intense as the amount of salt in the path of the beam of light is increased; the more diffuse a band the greater the widening under these conditions.

It was found that the finer absorption bands are different for the same salt in different solvents, and for different salts of the same metal in the same solvent. There may be a difference in the number of the bands present; there may be a difference in the intensity and width of the bands, or the difference may be in the wave-lengths of the bands. The different salts of neodymium in the same solvent often give very different absorption spectra, and, what is more important, the same salt of neodymium in different solvents often shows very different spectra. A neodymium salt dissolved in isomeric organic solvents frequently shows absorption lines and bands characteristic of the solvents. This is very important as showing the existence of "solvent bands," on account of the bearing on the solvate theory of solution.

The absorption spectra of a number of very rare substances were photographed and studied. These were salts of gadolinium, dysprosium, and samarium. Ample quantities of these substances were loaned to Dr. Strong by Urbain, and this phase of the work was thus made possible.

Dysprosium and samarium salts show very sharp, characteristic absorption bands, which are almost as interesting as those of salts of neodymium.

The second problem investigated was the spectrophotography of certain chemical reactions, or the changes produced in the spectra while certain chemical reactions are taking place.

We studied especially the action of oxidizing agents on uranous salts, using both milder and stronger oxidizing agents, and dissolving the uranous salt in single solvents and in mixed solvents. When uranous chloride is dissolved in a proper mixture of water and alcohol, both the "water" and "alcohol" bands come out simultaneously on the plate. While it is true in general that the "water" bands are the most persistent of all the solvent bands, yet a weak oxidizing agent oxidized the "hydrated" salt and left the "alcoholated" salt unaffected. A strong oxidizing agent, on the other hand, oxidized both the "hydrated" and the "alcoholated" salt. This is, therefore, an example of "selective oxidation," or selective action of chemical reagents on solvents, and, so far as is known to the writer, the first example thus far discovered.

The addition of aluminium and calcium chlorides to solutions of colored chlorides seems to increase the persistency of the alcohol bands relative to the water bands; and in partial precipitation from unmixed solvents the filtrate sometimes shows the presence of only one solvate. This may be denoted as "selective solvate precipitation." A possible spectroscopic method of determining the relative strengths of acids was pointed out.

The effect of rise in temperature on the absorption spectra of non-aqueous solutions was studied up to nearly 200°, and this was the third problem investigated during the year. This investigation was carried out in a closed cell devised for the purpose.

The general effect of rise in temperature is to deepen the color of solutions of inorganic salts. This is due to a widening of the absorption bands with rise in temperature, up to the highest temperatures studied. It was found for every pure salt dissolved in a single solvent that the absorption bands widen with rise in temperature; at the same time they become more diffuse and the edges hazier. There is a very great increase in the absorption of all solutions in the short wave-length region of the spectrum as the temperature is raised.

The effect of rise in temperature on the absorption spectra of neodymium salts in mixtures of alcohol and water, where both the "water" and "alcohol" bands appear simultaneously, was studied. With rise in temperature the "water" bands were more affected than the "alcohol" bands, showing that the "hydrates" are less stable with rise in temperature than the "alcoholates." It was also found that the acid aggregates formed by the action of acids on neutral uranous salts are more stable with rise in temperature than the neutral aggregates formed by the interaction of salt and solvent.

A study of all the facts brought out in this work, which has now been in progress for five years, has led to a theory of absorption spectra which seems to account for the facts, and which we believe will prove helpful, at least as a working suggestion. It is impossible in this brief report to discuss this theory or the work of the year in any detail. The whole work is now in press, and will soon be published by the Carnegie Institution of Washington as Publication No. 160.

The problems in spectroscopy now under investigation in this laboratory include the effect of ions as compared with molecules on the absorption spectra of solutions; the effect of rise in temperature on the absorption spectra of aqueous solutions; and the measurement of the intensity of absorption lines and bands by means of the radio-micrometer and thermoelectric junctions.

Morse, H. N., Johns Hopkins University, Baltimore, Maryland. Grant No. 689. *Measurement of the osmotic pressure of solutions.* (For previous reports see Year Books Nos. 2–9.) $1,800

The work of the past year has been mainly a continuation of that of the previous one. The object, as stated in the last report of progress, was to determine with all possible exactness the relation of osmotic pressure to temperature. Cane-sugar solutions, ranging in concentration from one-tenth weight-normal to weight-normal, have now been investigated at intervals of 5° between 0° and 25°, and the temperature coefficient within this field has been found to be identical with that of gases. The following tables present the results obtained, each result being a mean of two or more closely agreeing values. The total number of experiments represented is 147.

TABLE 1.

Temp.	Weight-normal concentration.									
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
	Mean osmotic pressure in atmospheres.									
°										
0	(2.462)	4.722	7.085	9.442	11.895	14.381	16.886	19.476	22.118	24.825
5	2.452	4.818	7.198	9.608	12.100	14.605	17.206	19.822	22.478	25.283
10	2.498	4.893	7.334	9.790	12.297	14.855	17.503	20.161	22.884	25.693
15	2.541	4.985	7.476	9.949	12.549	15.144	17.815	20.535	23.305	26.189
20	2.590	5.064	7.605	10.137	12..748	15.388	18.128	20.905	23.717	26.638
25	2.634	5.148	7.729	10.296	12.943	15.624	18.434	21.254	24.126	27.053

TABLE 2.

Temp.	Weight-normal concentration.									
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
	Ratio of osmotic to gas pressure.									
°										
0	(1.106)	1.061	1.061	1.060	1.0685	1.0765	1.083	1.093	1.104	1.115
5	1.082	1.063	1.058	1.059	1.067	1.074	1.084	1.093	1.102	1.115
10	1.082	1.060	1.059	1.060	1.066	1.073	1.083	1.092	1.102	1.113
15	1.082	1.061	1.061	1.059	1.068	1.073	1.083	1.093	1.102	1.115
20	1.084	1.062	1.060	1.060	1.067	1.073	1.084	1.093	1.103	1.115
25	1.084	1.059	1.060	1.059	1.065	1.071	1.083	1.093	1.102	1.113
Mean..	1.083	1.061	1.060	1.060	1.067	1.074	1.083	1.093	1.103	1.114

Table 1 gives the osmotic pressures which were observed, and table 2 the ratio of these to the corresponding calculated gas pressures. It will be observed, on referring to table 2, that the ratios for each concentration are constant to the third decimal place, which would seem to establish sufficiently the fact that up to 25° the law of Gay-Lussac for gases applies also to the osmotic pressure of cane-sugar solutions. A possible exception will be noted in the case of the one-tenth normal solution at 0°, where the ratio of osmotic to gas pressure was found to be 1.106 instead of 1.083, as in the case of the same solution at 5°, 10°, 15°, 20°, and 25°. This apparent anomaly makes necessary a careful investigation of more concentrated solutions at temperatures very near their respective freezing-points; *i. e.*, at temperatures below 0°. The question is whether other solutions than that cited above undergo an apperent concentration just above their freezing temperatures.

Much attention has been given during the past year to testing in various ways the validity of the results which were being obtained. Two lines of investigation of this character may be mentioned:

(1) In nearly every experiment hitherto reported the initial pressure in the cell has been less than the ultimate or osmotic pressure. The question was to be answered, whether the same ultimate pressure would be obtained if the initial pressures were higher than the final ones. It has been shown

conclusively that the same result is obtained whether the initial pressure is below or above the final one. When the slight difference in concentration is corrected for, the osmotic pressures are identical.

(2) Owing principally to scarcity of approved manometers and lack of bath accommodations, the cells, in former years, have been opened, as a rule, after having maintained an apparently maximum pressure from 24 to 72 hours. During the past year it has often been practicable to keep cells in the bath for much longer periods. The conclusion reached is that, if a cell develops and maintains a given pressure for 24 hours, no further increase in pressure is to be expected. Concurrently the durability of the membrane has been tested. In one instance a cell containing a 0.5 normal solution was left in the bath for 60 days after it had developed maximum pressure. On the sixty-first day the pressure was the same as on the second, namely, 12.522 atmospheres, and all the intermediate fluctuations were smaller than the corresponding variations in atmospheric pressure. There is no known reason for believing the membrane in this cell to have been superior to any of the others employed in obtaining the pressures cited above.

An account of the completed investigations of the past two years has been published in the American Chemical Journal in a series of five papers under the general title of "The relation of osmotic pressure to temperature." The separate titles are given below:

I. The manufacture of the cells employed in the measurements (vol. XLV, p. 91).
II. The manometers (vol. XLV, p. 237).
III. The regulation of temperature (vol. XLV, p. 383).
IV. The membranes (vol. XLV, p. 517).
V. The measurements (vol. XLV, p. 554).

While the ratio of osmotic to gas pressure is constant for each concentration up to 25°, showing that the law of Gay-Lussac for gases applies also to osmotic pressure, that ratio is in every case greater than unity and varies from one concentration to another. In other words, there is no direct experimental evidence in the conduct of cane-sugar solutions at temperatures not exceeding 25° that the law of Boyle likewise applies to osmotic pressure. The high ratios in question are not, however, to be accepted as evidence adverse to the law, for they may be due to some form of molecular association, *e. g.*, hydrates. It is to be expected, if such aggregations exist, that at some higher temperature they will begin to break down, and that the solutions will give, therefore, smaller ratios of osmotic to gas pressure than have been obtained at 25° and below. Hence it became of importance to measure the osmotic pressure of cane-sugar solutions at temperatures above 25°, and work along this line has been in progress during the past year. The baths hitherto employed are not adapted to work at high temperatures, and others have been designed and tested which enable us to measure osmotic pressure at temperatures up to the boiling-point of water. A number of determinations of pressure at 30°, 35°, 40°, and 50° have already been made, and it has been found that, even at 30°, the ratio of osmotic to gas pressure is, for every concentration, decidedly smaller than between 0° and 25°; *i. e.*, that the solutions apparently become more dilute as the temperature rises from some point between 25° and 30°. It is now to be ascertained, for each concentration, at what temperature this apparently progressive dilution reaches a maximum, and whether the maximum is in every case that which gives the unit ratio of osmotic to gas pressure.

The author of this report has had, during the past year, the uninterrupted cooperation of Drs. W. W. Holland and C. N. Myers.

Mr. J. L. Carpenter has carried out an elaborate investigation of a number of manometers of a new form which it is proposed to use in the future.

Mr. G. Cash has made a number of preliminary determinations of osmotic pressure at the higher temperatures.

Mr. A. D. Holmes has investigated the ferro-cyanides of zinc and cobalt with reference to their semi-permeable character, and has proved that the latter is serviceable for the measurement of osmotic pressure, while the former is worthless for that purpose.

Mr. J. L. McGhee has investigated the ferro-cyanide of nickel, and has shown that, as a membrane, it is probably superior to the ferro-cyanide of copper.

Noyes, Arthur A., Massachusetts Institute of Technology, Boston, Massachusetts. Grant No. 706. *Researches upon the physical properties of aqueous solutions in relation to the ionic theory.* (For previous reports see Year Books Nos. 2–9.) $3,000

The following lines of research have been pursued during the past year:

With the aid of Dr. W. C. Bray, Dr. W. D. Harkins, and Mr. W. J. Winninghoff, new determinations of the effect of salts on the solubilities of other salts have been made, and the experimental material obtained in this laboratory during the preceding years has been discussed from a theoretical standpoint and prepared for publication. The results show that the ratio of the activity to the concentration of univalent ions decreases slightly, and the corresponding ratio for the un-ionized portion of the salt increases markedly, with increasing concentration of the salts or ions in the solution; and therefore, that the deviations from the theoretical dilution law exhibited by uni-univalent salts arise mainly from the abnormal influence of the un-ionized substance. The influence of the common bivalent ion on the solubility of unibivalent salts is shown to be so extremely abnormal that the activity of such ions can not be even roughly proportional to their concentrations. In other words, the solubility-product principle based on the law of mass-action is shown to lead to utterly erroneous results when applied to a moderately soluble unibivalent salt in the presence of another salt having the same bivalent ion. It has been shown that this remarkable result is probably due to the presence of intermediate ions (such as $AgSO_4^-$, $ClPb^+$) in considerable proportion in the solutions of such salts.

With the cooperation of Dr. K. G. Falk, the work of preparing a summary and critical discussion of existing data on the properties of salt solutions in relation to the ionic theory has been continued. Two papers—one on mol-numbers derived from freezing-point lowering, and one on electrical transference numbers—have already been published; and a third one, on the electrical conductance of solutions, is ready for publication.

A research on the conductance and ionization of two salts of high-valence types (namely, of the uniquadrivalent and of the uniquinquivalent type) has been completed with the assistance of Mr. R. H. Lombard. The principles in regard to ionization referred to in earlier reports are shown by the investigation to be applicable to salts of these higher types.

An investigation of the electromotive force of concentration-cells of the form Hg, Hg_2SO_4, K_2SO_4 sol. of conc. C_1, K_2SO_4 sol. of conc. C_2, Hg_2SO_4, Hg has been carried on by Dr. W. C. Bray and Mr. P. V. Farragher with the view of determining the activity of the bivalent ion by an independent method. The results already obtained confirm the conclusion that such bivalent ions exert a very abnormal influence.

Richards, Theodore W., Harvard University, Cambridge, Massachusetts. Grants Nos. 570, 626, and 707. *The exact determination of atomic weights and other fundamental physico-chemical constants.* (For previous reports see Year Books Nos. 2–9.) Each grant, $2,500

A number of investigations were carried on at the Chemical Laboratory of Harvard College with the aid of these grants, as follows:

(1) *Compressibilities and Surface Tensions:*

Dr. C. L. Speyers assisted in continuing the work on the compressibilities and surface tensions of organic substances, and obtained many interesting results. The data are far too numerous for detailed statement here, but the following table, containing a few typical figures, is so suggestive that it is worthy of presentation. The substances employed were all of a high degree of purity.

Properties of the xylenes.

	Boiling-point.	Density, 20°/4°.	Surface tension (mg./mm.; 20°).	Compressibility $\times 10^6$ at 20°.
o-xylene...........	144.0°	0.8811	3.09	60.1
m-xylene.........	139.0	0.8658	2.96	63.6
p-xylene	136.3	0.8611	2.92	66.3

NOTE.—The compressibilities are in terms of kg./cm., over the range 100 to 500 atmospheres.

It will be observed that these properties all vary in such a sense that the substance with higher boiling-point possesses greater density and surface tension, as well as less compressibility. These relations, which appear to hold in about 80 per cent of the cases thus far studied, are in accord with the theory of compressible atoms. The Faraday Lecture of June 1911 contains a further exposition of this matter. Dr. Speyers also spent much time in recalculating and reducing to a consistent basis previous results concerning the properties of many substances, thus laying the basis for further research and comparison.

(2) *The Heats of Solution of Metals:*

Dr. T. Thorvaldson devoted the winter to the improvement of the thermochemical technique involved in the solution of metals in acids, under the author's direction. Last year, with the help of Dr. L. L. Burgess, it had been shown that Thomsen's methods and theory were both essentially faulty, and the way had been paved for further advance. A few remaining defects of detail were eliminated during the present work. A full description of the somewhat complicated devices employed will be published as soon as possible.

(3) *The Heat of Solution of Barium:*

In connection with the work of Dr. Thorvaldson, the study of the extremely reactive metal barium was begun with the help of Dr. H. E. Bigelow. This element presents a problem of unusual difficulty, because of the extraordinary precautions needed to obtain it in a pure state. Finally, by repeated distillation, with the help of an electric furnace at 1200° in a very low vacuum and with special precautions, it was possible to accomplish the result desired. Suboxide and hydride are the two impurities most difficult to eliminate; the method of Guntz is not wholly adequate to effect their removal. The heat of solution of the metal may now be determined with precision; the importance of this datum may be inferred from its place in the last diagram given in the Faraday Lecture.

(4) *Heats of Neutralization:*

The work on the heat of neutralization of acids and bases was continued with the help of Dr. A. W. Rowe, other acids and bases being added to the list. It is hoped that before the next report this work may appear in print.

(5) *Heats of Combustion of Organic Isomers:*

Previous work, carried out with the help of Drs. Henderson, Frevert, and Jesse, had perfected the technique of thermo-chemical work with volatile liquids, and opened the way for further careful investigation. This was taken up during the past winter with the help of Dr. F. Barry. Residual work in other lines prevented him from progressing far; but a number of hydrocarbons of exceptional purity were prepared, and it is hoped that they may be made the subject of thorough research during the coming winter.

(6) *The Atomic Weight of Silver:*

One point was avowedly left incomplete in the recent research of Richards and Willard concerning the atomic weights of silver and lithium, namely, the question as to whether or not fused lithium perchlorate still retains water after having been heated for a long time to 300° in a stream of dry air. This point, of great importance in its bearing on the atomic weight of silver, was attacked last winter with the help of T. S. Woodward. The positive detection of minute traces of water is always a very difficult matter, and the search in this case was especially perplexing and is not yet concluded; nevertheless it is safe to say that the results thus far indicate the almost if not quite complete absence of water from the fused perchlorate.

The preparation for publication of such portions of these and previous investigations as have been finished was greatly delayed during the past winter by two circumstances, namely, the writing of the Faraday Lecture and the planning of the new Wolcott Gibbs Memorial Laboratory. This building, to be erected by means of funds generously subscribed by friends of Harvard University, will greatly improve the conditions of experimentation. It is hoped that thereby the funds of the Carnegie Institution of Washington may be used to greater advantage than before.

GEOLOGY.

Chamberlin, T. C., University of Chicago, Chicago, Illinois. Grant No. 708. *Study of fundamental problems of geology.* (For previous reports see Year Books Nos. 2–9.) $4,000

The work of the year under this grant has been an extension of that of last year on the secular maintenance of the atmosphere. The work has deployed into several special lines inseparably connected with the problems of maintenance, but which also lie in the broader field of paleo-climatology, and the scope of the paper in preparation has been extended.

Moulton, F. R., University of Chicago, Chicago, Illinois. Grant No. 709. *Investigations in cosmogony and celestial mechanics.* (For previous reports see Year Books Nos. 4, 5, 8, and 9.) $2,000

During the last year the following papers have been published:

(1) The straight line solutions of the problem of N bodies. The Annals of Mathematics, vol. 12, No. 1, pp. 1–17. Oct. 1910.
(2) (In collaboration with Dr. W. D. MacMillan.) On the solutions of certain types of linear differential equations with periodic coefficients. American Journal of Mathematics, vol. 33, No. 1, pp. 63–96. Jan. 1911.
(3) The influence of astronomy on mathematics. Science, vol. 33, pp. 357–364. Mar. 1911.

During the last year the following book and papers have been completed and accepted for publication:

(1) Periodic Orbits, a book of 855 manuscript pages, which will be published by the Carnegie Institution of Washington.

(2) The Problem of the Spherical Pendulum from the Standpoint of Periodic Solutions. This paper is in type for Rendiconti Matematico di Palermo.

(3) New Expansion of Elliptic, Hyperelliptic, and Related Periodic Functions. This paper will appear in the American Journal of Mathematics.

(4) Periodic Orbits of Superior Planets. This paper has been accepted for publication by the Transactions of the American Mathematical Society.

During the last year the following investigations, which are not yet in shape for publication, have been made:

(1) On the Theory of the Origin of Binary Stars by Capture. This paper was read before the St. Louis meeting of the National Academy of Sciences, November 8, 1910.

(2) On the Evolution of Periodic Orbits. This paper was read before the National Academy of Sciences at Washington, April 20, 1911.

GEOPHYSICAL RESEARCH.

Adams, Frank D., McGill University, Montreal, Canada. Grant No. 693. *Completion of investigation into the flow of rocks.* (For previous reports see Year Books Nos. 2–7 and 9.) $800

The work during the past year has consisted in the completion of certain lines of the investigation and the further prosecution of others, with a view to bringing the whole investigation to a close by the end of the current year.

Additional experiments were made on the amount of cubic compression to which granite and other rocks of high resistance must be subjected in order that all cavities and empty spaces existing in them should be closed. This investigation has now been completed and the results will appear shortly.

The study of the deformation of diabase and granite, as well as of certain varieties of hard, impure limestones, has been continued and is also now completed, so far at least as it is proposed to follow out the investigation of this interesting subject under the present grants from the Carnegie Institution of Washington. A complete account of the results obtained is now being prepared for publication.

A series of experiments has also been carried on during the year on the structures developed by the recrystallization of various chemical compounds while subject to movement under the action of high differential pressures. This investigation has for its object the securing of information concerning the processes at work in the development of those crystalline schists which owe their structure to recrystallization. The results obtained up to the present time are of considerable interest, but it is intended during the remainder of the year to prosecute the investigation still further in the hope of obtaining results which will have a direct bearing on the question of the origin of this group of the crystalline schists.

CLASSICS OF INTERNATIONAL LAW.

Scott, James Brown, General Editor, Washington, District of Columbia.

Professor Holland has completed his edition of Zouche and Mr. Brierly has made a very careful translation of the Latin text. The two volumes have just been issued.

Professor Westlake has also finished his editorial work on Ayala and Mr. Bate's translation of the Latin text has been completed. It is expected that these two volumes will be published before the close of the present year.

Professor von Bar's introductions to the proposed editions of Rachel and Textor have been received, but the translations have not been made as yet. The translators will be selected soon.

Professor de Lapradelle's introduction to Vattel has not yet been received, but is definitely promised. The text has been reproduced photographically and the translation is in progress.

Professor Jellinck reported shortly before his death that he had finished the introductions to the two works of Wolf to be included in the series. They have not, however, been received as yet, and it may prove that they need further revision.

The translation of the De Jure Belli ac Pacis of Grotius by Rev. John D. Maguire is substantially completed, and will be submitted for printing at an early date.

The De Jure Prædæ exists in manuscript form in the Library of the University of Leyden and is now being photographed for the series. As soon as this difficult task is accomplished, Dr. Maguire will set himself to its translation. There is no English version of this important work, which, interesting in itself, throws much light upon the great masterpiece of 1625. The reproduction of the manuscript by photography will be appreciated by scholars as an extraordinarily interesting example of the Latin of scholars of the sixteenth century, while the English translation will place the text within the reach of the general reader.

MATHEMATICS.

Morley, Frank, Johns Hopkins University, Baltimore, Maryland. Grant No. 647. *The application of Cremona groups to the solution of algebraic equations.* (For previous report see Year Book No. 9.) $1,000

Under the grant of 1910–11 Dr. J. R. Conner has conducted an investigation of rational curves, regarding them as projections of the so-called norm-curves. He has given special attention to the cases of the quintic and the sextic and has written a memoir on each, which will appear during the coming year.

The salient point of the memoir on the quintic is the use made of multiple correspondences; that of the memoir on the sextic is the covariant surfaces of the sextic in space; one of these covariants is Cayley's symmetroid, so that we have a new and effective method of investigating this surface.

LITERATURE.

Sommer, H. Oskar, Astolat, Camberley, Surrey, England. Grants Nos. 650 and 725. *Completion for publication of researches on Arthurian Romances.* (For previous reports see Year Books Nos. 5–9.) $5,000

1. I have completed the second revise of volumes IV and V and provided headlines and sidenotes.
2. I have completed the final revise of volume IV.
3. I have completed the final revise of volume V as far as I have received it.
4. I have finished the first revise of the whole of volume VI.
5. I have done the preliminary work for the index raisonné for volumes I and II.
6. Whatever leisure I have found I have devoted to the preparation of a volume dealing with the fragments of the French original of the pseudo Robert de Borron's trilogy from the Holt MS. and the MSS. Nos. 112, 342, and 343 at the Bibliotheque Nationale.

The following work remains to be done:

1. The remainder of the final revise of volume V.
2. The second and third revises of volume VI and the preparation of headlines and sidenotes.
3. The passing through the press of the Livre d'Artus of the MS. No. 337 for volume VII.
4. The compilation of the analytical index to the seven volumes.

METEOROLOGY.

Bjerknes, V., University of Christiania, Christiania, Norway. Grant No. 695. *Preparation of a scientific work on the application of the methods of hydrodynamics and thermodynamics to practical meteorology and hydrography.* (For previous reports see Year Books Nos. 5–9.) $1,200

Of the work "Dynamic Meteorology and Hydrography" the first part, "Statics," by V. Bjerknes and J. W. Sandström, has appeared. The second part, "Kinematics," by V. Bjerknes, Th. Hesselberg, and O. Devik, is in press.

NUTRITION.

Osborne, T. B., Agricultural Experiment Station, New Haven, Connecticut. Grant No. 692. *Comparative study of the more important vegetable proteins.* (For previous reports see Year Books Nos. 3–9.) $8,000

During the past year the feeding experiments, referred to in our last report as being undertaken in cooperation with Prof. Lafayette B. Mendel, of Yale University, under a grant from the Adams Fund, have so increased in scope and presented so many opportunities for fruitful research that it has been found necessary to direct a large part of the work done under this grant to supplementing the resources derived from the Adams Fund. Consequently much time has been devoted to the preparation of suitable materials with which to conduct these feeding experiments, for it has been essential to their success that only protein preparations of the highest purity should be used. The labor thus required has made it necessary to postpone, for the present, some of the work which in our last report was described as nearing completion.

The work on the proteins of hemp seed has advanced but little during the present year, and an extensive investigation of the proteins of maize, which was planned as a part of the year's work, has not gone beyond a substantial beginning.

The study of the anaphylaxis reaction, undertaken in cooperation with Prof. H. Gideon Wells, of the University of Chicago, has been carried to a point where the results have been published in the Journal of Infectious Diseases, vol. VIII, p. 66, 1911, as part I of a proposed series of papers on the biological reactions of the vegetable proteins.

The investigations of the methods used in determining the proportion of the products of decomposition effected by boiling proteins with acids has been continued and most of the results obtained during the past year have been published in the American Journal of Physiology, vol. XXXVI, p. 420, 1910, and Journal of Biological Chemistry, vol. IX, p. 333, and p. 425, 1911. The products of hydrolysis of gliadin from wheat flour have been analyzed with results materially higher than those obtained in the earlier analyses. Additional information respecting deficiencies in the analytical methods has been secured, and we now have information of greater value than that which we formerly had respecting this important protein. A similar study of the products of hydrolysis of casein from cow's milk has also yielded a much better knowledge of the products of decomposition of this important protein. An analysis of edestin has also been completed with results of similar value. These analyses were undertaken not only to increase our knowledge of the deficiencies of the analytical methods, but also to supply us with more accurate information respecting these three proteins which in their chemical constitution represent distinctly different types and which have formed the basis of comparison in most of our feeding experiments.

The experimental feeding of white rats, which was instituted for the purpose of determining the relative nutritive value of different proteins, has given results of such interest and importance that our chief efforts have been directed to their successful conduct. During the first year it was learned that rats could be maintained for much longer periods than had before been supposed possible if fed on combinations of isolated foodstuffs containing a properly chosen mixture of inorganic substances. During the progress of this work fire destroyed our laboratory, together with all the experimental animals, and consequently none of the experiments had then been carried on long enough to determine the fact that after about six months of such feeding most of the animals suddenly begin to decline and soon die unless supplied with food. It has become evident from these investigations that the experimental food used during the first year of our work was not suitable to meet all nutritive requirements of the animal.

While these experiments were in progress control experiments were being conducted with mixtures containing milk powder, since with this the physical condition of the experimental foods could be closely imitated and all the essential elements of a food of known value could also be supplied. Animals on this food are still in fine physical condition after nearly two years, have reproduced normally, and give every evidence that they can thus be maintained under the experimental conditions throughout their natural lifetime.

As a result of this observation we have sought in the non-protein part of the milk the essential elements lacking in the artificial food mixtures previously used. Accordingly the fat and protein were removed from the milk and the residue obtained as a powder by evaporating to dryness. In order to imitate the successful mixture containing the whole milk powder, we made a food containing 28.2 per cent of the non-protein milk powder, 25 per cent of pure lard, 23.8 per cent of starch, 5 per cent of agar, and 18 per cent of one or another of the proteins to be tested. By using such foods we have compared the nutritive effect of casein from cow's milk, edestin from hemp seed, gliadin from wheat, glutenin from wheat, zein from maize, glycinin from the soy-bean, ovalbumin from hen's egg, and lactalbumin from milk, These proteins were chosen because they differ widely in their chemical constitution.

The foods containing each of the above-named proteins in the proportions employed have thus far served equally well to meet the nutritive requirements of the mature rats, with the sole exception of the food which contained zein. Although the rats ate a sufficient quantity of this zein food, they constantly and rapidly declined in weight from the very beginning of the experiment. Of the proteins thus tested, zein is the only one which on hydrolysis yields no tryptophane, and it is highly probable that its failure to maintain the animals was due to this deficiency. The chemical constitution of tryptophane indicates that it is the source of several physiologically important constituents of the animal organism, and it is almost certain that this amino-acid is essential for the maintenance of life.

In respect to the question of synthesis of amino-acids by the animal organism, our experiments have already afforded information which indicates that such syntheses occur to a much greater extent than has formerly been assumed. Thus, with the quantities used, casein which lacks glycocoll, and gliadin which lacks glycocoll and lysine, have the same nutritive value as those proteins which yield all the known products of protein decomposition. The experiments conducted during the past year have established beyond a question that, by the methods now employed, it is possible to continue the experimental feeding long enough to obtain answers to many questions concerning the chemistry of nutrition. Since nearly all our animals are still in fine health and apparently normal condition after several months of experimental feeding with the food mixtures containing protein-free milk, it seems probable that such experiments can be continued throughout the greater part of the natural life of the animal, and thus afford an opportunity to study many of the more intricate problems of physiological chemistry.

The experiments just mentioned concern only the maintenance of mature animals. More important and interesting, however, are the results of our experiments in feeding young and growing animals. When young rats are fed with mixtures of isolated food substances, such as were used with a considerable degree of success during the first year's work, they can be maintained in apparent health and activity for many months, but make little or no growth. Measurements of several rats thus stunted, which have kindly been made for us by Drs. Donaldson and Hatai, have shown that in respect to the proportion of all their parts these stunted rats had remained of the same size as at the beginning of the experiment. The only evidence of development was shown by the water content of their brains, which was normal for their age. Thus, while their brains had not increased in size, their brain tissue had matured.

The outcome of these experiments is interesting in connection with the attempts of other investigators to retard the growth of animals by supplying an insufficient quantity of normal food. In such cases, while the animals remained stationary in weight their skeletons and nervous systems developed at the expense of their muscular tissue.

When young rats are fed on mixtures containing *protein-free* milk and one or another of the pure proteins, they make normal growth on all of the proteins thus far tried with the exception of those soluble in alcohol, which are obtained from the seeds of the cereals. When the food mixtures contain only these latter proteins (we have thus far used gliadin from wheat and hordein from barley), the experimental animals have been kept in excellent nutritive condition throughout periods which have now reached nearly one year and give promise of continuing successfully much longer. Several animals have thus been fed from the time of weaning until they should have attained almost their maximum size, but without making more than the slightest growth. Many experiments are now in progress to determine the effect of such arrested growth on the subsequent development of the animals, but as yet the experiments have not been continued long enough to furnish data suitable for publication.

The results of these investigations conducted during the past two years have been summarized in the publications of the Carnegie Institution of Washington, Publication No. 156, just issued, and in Publication No. 156, part 2, now in press.

PALEONTOLOGY.

Case, E. C., University of Michigan, Ann Arbor, Michigan. Grants Nos. 559 and 611. *Continuation of work upon the vertebrate fauna of the Permian period in North America.* (For previous reports see Year Books Nos. 2, 4, 8, and 9.) $3,200

Two monographs, "A revision of the Cotylosauria of North America" and "A revision of the Amphibia and Pisces of the Permian of North America," Publications Nos. 145 and 146 of the Carnegie Institution of Washington, have been completed and will appear before the end of the year 1911. These are the second and third monographs in the series dealing with the vertebrate fauna of the red beds of North America, commonly regarded as of Permian or Permo-Carboniferous age. The first of the series, a monograph entitled "A revision of the Pelycosauria of North America," has already been issued by the Carnegie Institution as Publication No. 55. The fourth and concluding monograph of the series will deal with the conditions of deposition of the Permian, the paleogeography of the period, and the factors which governed the development and distribution of the fauna.

Publication No. 145 has 122 pages, 52 figures, and 14 plates. It deals with the most primitive group of reptiles found in the beds, describing the anatomy and relationships of the various forms and their general relationship to the similar forms found in Europe and Africa. An important part of the monograph is the collection of the original descriptions of types by earlier authors, which have been printed in scattered papers and were difficult of access. A revised description of the known forms and descriptions of new forms follows the original descriptions. The pioneer work by older authors left the taxonomy of the group in bad shape, and it is hoped that this has been satisfactorily cleared up and a good basis for future work established.

Publication No. 146, 184 pages, 56 figures, and 32 plates, treats the Amphibia in the same manner as the Cotylosauria, collecting the original descriptions, giving revised descriptions, correcting the taxonomy, and adding much that is new. The work upon the fishes has been carried on in the same way as that upon the Amphibia, but is the work of Dr. Louis Hussakof, of the American Museum of Natural History in New York. A description of two new fossil cockroaches from the Permian of Texas is the work of Professor Sellards, of the University of Florida.

The basis of the monographs is the material in the collections of the American Museum of Natural History in New York, Yale University, the University of Chicago, and the Alte Akademie of Munich. This includes all of any importance which has come from the Permian of North America. All material published up to the date of the completion of the manuscript has been reviewed, and all known forms described and fully illustrated.

PHILOLOGY.

Hempl, George, Leland Stanford, jr. University, California. Grant No. 629. *Researches on the origin and nature of Runic inscriptions and on the Etruscan language.* $1,000

Professor Hempl's first grant was used in defraying traveling expenses while searching for Runic material in Europe in the summer and fall of 1906 and the summer of 1907. The second grant has been partly expended for books and material.

Dr. Hempl's former report recorded:

(1) The discovery that in many early Runic records a system of writing was employed that was transitional between syllabic and alphabetic. To this Dr. Hempl has recently given the name "penalphabetic," because it is almost alphabetic.

(2) The consequent solution of many hitherto unread Runic texts, which give new information as to earliest Germanic speech.

(3) The discovery of a new Old-Germanic language, namely, Burgundian.

(4) The detection of errors in the current understanding of Venetic letters, and success, therefore, in reading Venetic, which turned out to be a conservative Italic dialect, closely related to Latin.

(5) The successful effort to read Etruscan, and the discovery that this language was a very radical member of the group to which Latin and Venetic belonged.

His second report adds:

(6) The discovery that the ancient Cretan pictographic inscriptions represent a system of writing in which each device stands for the initial sound or sounds of the Greek name for the object represented, the system being thus one of crude syllabic writing.

(7) The discovery that the language employed in these inscriptions was Greek, and Greek of the variety known to us as Attic.

(8) The consequent establishment of the fact that the remarkable ancient Cretan civilization, the remains of which have been laid bare by Evans and other archeologists during the past ten years, and which so long antedates what we know as Greek civilization, was itself Greek. This puts written Greek some 1,500 years farther back than the oldest records hitherto read—farther back, indeed, than the date now generally (perhaps erroneously) assigned to the oldest Sanskrit.

(9) The discovery that the celebrated Phæstos disk is written in a highly developed system of syllabic writing, and that the language employed is Ionic Greek.

(10) Success in working out, in much detail, the phonological, monophological, and accentual laws of the Etruscan language.

Some record of Dr. Hempl's Runic and Burgundian studies will be found in:

(1) An article in the Nation, April 23, 1908.

(2) An article in the Transactions of the American Philological Association, 1909.

A preliminary report on some of his Cretan studies appeared in Harper's Magazine for January 1911.

The first report on his Etruscan studies has just been issued as an advance reprint from the forthcoming Matzke Memorial volume, published by Leland Stanford, jr. University.

PHYSICS.

Barus, Carl, Brown University, Providence, Rhode Island. Grant No. 697. *Continuation of study of the properties of condensation nuclei.* (For previous reports see Year Books Nos. 4, 5, 7–9.) $500

In the forthcoming theoretical account of elliptical interferences, the author has shown the practical advantages attained by associating the interferences of thin plates with the diffractions of a transparent grating—a subject originally suggested to him by the phenomenon of coronas in which a marked interference phenomenon is also superimposed on the diffractions. These elliptic fringes may, however, be evoked in other ways than those discussed in the report specified, and a number of these were investigated during the present year.

For instance, let the oblique mirror of Michelson's apparatus be the usual plate of glass and replace the two opaque mirrors (usually called M and N) by identical small reflecting gratings set at the angle of diffraction of the spectrum, symmetrically to the incident rays. Here the elliptic interferences will be seen in the telescope at right angles to the rays issuing from the collimator. This adjustment is an inversion of the plan of returning the diffracted spectra normally to the oblique transparent grating and the interpretation may be made along the same lines. The rings, however, are more liable to be distorted, depending on the adjustment and ruling of the halved gratings.

Again, in a simple spectrometer adjustment for grating spectra (either by transmission or by reflection), suppose the grating to be separated into two halves by a division parallel to the ruling; then on displacing one of the halves, micrometrically, parallel to itself from its original coplanar position, interference shows itself in a way which is perhaps the most direct of any of the methods hitherto treated. These fringes are rigorously straight, parallel to the slit, and their size depends on the distance apart of halves of the grating, both parallel and normal to its original plane. They vanish after reaching maximum size, but do not pass through infinity when the halves are merely coplanar. The results have been treated in detail and they have a bearing on the colors of coronas, inasmuch as spectra from sources in parallel planes at a short distance apart along their normals are brought to interfere.

To test some of the equations deduced, it is necessary to know the index of refraction of the glass of the grating for all wave-lengths. Hence the author has spent considerable time in devising methods by which the refraction of plate glass may be found in all parts of the spectrum, by a general procedure, in which total reflection is combined with diffraction. This has been worked out with a degree of precision corresponding to its probable importance in practical work.

The dependence of the size and color of coronas on the thickness of the cloud-layer producing the display was tested by a sensitive method, in which the coronas due to different thicknesses of layer could be superposed. No difference of character could be detected, a result of importance in connection with the theory of coronas.

In relation to the occurrence of vapor nuclei in dust-free wet air, the author has constructed a small type of fog chamber, by which such nuclei may be caught to the number of several million per cubic centimeter and of a corresponding degree of small size.

The author has, moreover, returned to the moot subject of persistent nuclei produced by the X-rays, or any other sufficiently intense cause of ionization, with a view to determining the density of ionization which must be produced if persistent nuclei are to appear. It was found that the number of ions must exceed at least 300,000 per cubic centimeter to be accompanied by persistent nuclei. If we imagine the ionization to be under its own specific kinetic pressure, then if this reaches a definite value a kind of condensation occurs very similar to the case of a vapor, and the persistent nuclei are the result.

Finally, the author has made a large number of experiments on the diffusion of gases through liquids in the elucidation of more remote parts of the present subject.

Howe, H. M., Columbia University, New York, New York. Grant No. 698. *Determination of the refining temperature of steel.* (For previous reports see Year Books Nos. 6–9.) $500

Steel in its slowly cooled state (the state in which it is used for structural purposes, rails, beams, boiler and ship plates, etc.) is a granitic or conglomerate mass, consisting of (1) pearlite, a eutectoid mechanical mixture of particles of nearly pure metallic iron called *ferrite,* and the iron carbide Fe_3C called *cementite;* and (2) of masses of either this ferrite or this cementite in a free state; *i. e.,* not intertwined as pearlite. In hypo-eutectoid steels, *i. e.,* those with less than about 0.90 per cent of carbon, the conglomerate consists of pearlite with free ferrite; in hyper-eutectoid steels, *i. e.,* those with more than about 0.90 per cent of carbon, it consists of pearlite with free cementite.

When such steel, whether hypo-eutectoid or hyper-eutectoid, is heated up through a certain critical or transformation range, of which the lower boundary is at about 725° C., and the upper varies from 725° to 1130°, according to the carbon content, this conglomerate mass is completely transformed, its several components merging to form the solid solution called austenite, which in slow cooling again splits up into a conglomerate like that of its initial state; but when it is cooled rapidly from above this transformation range, differentiation into the old conglomerate condition is obstructed, so that the metal is arrested in some condition intermediate between that of that conglomerate state and austenite.

It has long been known that the free ferrite or cementite often forms well-marked cell-walls, inclosing kernels of pearlite often containing irregular grains or islands of ferrite or cementite. At other times this cellular structure is either fragmentary or wholly lacking, so that the mass consists solely of irregular grains of its several constituents. It has also long been known that the properties of the steel are affected profoundly by the size and arrangement of the constituent particles. But our fragmentary knowledge has been much confused by failure to distinguish between these composite cells and the individual grains.

The present investigation aims to trace the life history of these cells and grains. I have enunciated or re-enunciated the previously supposed or known laws, verified a number of those previously insufficiently proved, and discovered several additional laws. These laws follow:

(1) The cellular structure arises normally in one of the two differentiation processes, (*a*) solidification and (*b*) transformation from austenite into pearlite, etc. During this transformation each grain of mother austenite rejects to its outside the ferrite or cementite to which it gives birth, and thus sets up the cellular structure.

(2) This structure is unstable and thus represents an early stage in structural development. It breaks down through the spheroidizing and coalescence of the ferrite or cementite in its walls and that scattered through the kernels.

(3) The cell-size increases with the length and height of the heating above the transformation range. The rate of growth evidently increases as some relatively high power of the temperature is reached.

(4) The rate of cooling affects the cell-size only in so far as it affects the total opportunity for growth above the transformation range.

(5) Both long and high heating increase the stability of the cellular structure.

(6) The cellular structure is slower to develop and is more stable in hyper-eutectoid than in hypo-eutectoid steel.

The presence of manganese—

(7) Increases the extent of the areas free from coagulated and hence recognizable ferrite;

(8) Lessens the size of the individual cells, and of the individual ferrite grains; and

(9) Increases the stability of the cellular structure.

(10) The rate of grain-growth of the ferrite is inversely as the carbon-content of the steel.

Of these laws Nos. (1) and (3), even if hitherto unenunciated, have probably been in the minds of many investigators. The others I believe to be new. Nos. (4) and (10) need further confirmation. I do not give here the pre-existing laws which I have either proved or confirmed.

From law (5) and from other facts enumerated it is clear that the stability of the cellular structure and of the Widmanstättian figuring, which is identical with that of meteoric iron, and other structural features, are profoundly influenced by ante-natal conditions; *i. e.,* by the conditions to which the austenite is exposed before these structures come into existence. The relations between these scattered surprising effects are pointed out and an explanation of them is offered.

Nichols, E. L., Cornell University, Ithaca, New York. Grant No. 699. *Continuation of researches of phosphorescence and fluorescence.* (For previous reports see Year Books Nos. 4–9.) $3,000

The investigations during the past year have been largely devoted to the study of the fluorescence and of the absorption spectra of various uranyl salts.

The fluorescence of these salts has in every case a spectrum consisting of a group of narrow bands forming a spectral series of the type in which the differences of frequency are constant or approximately so. The absorption spectra likewise consist in every case of a group of bands similarly spaced but of shorter wave-length. The differences of frequency in the group of absorption bands are always less than in the fluorescence spectrum. The two groups overlap to such an extent that where seven bands of the fluorescence group are visible, three of these correspond to the three absorption bands of greatest wave-length.

In this overlapping region fluorescence and absorption are coincident as to wave-length, or very nearly so, and this coincidence of two overlapping series not having the same frequency difference is brought about by an abrupt change in both series. For example, we find in one instance the following differences:

Uranyl-potassium sulphate; wave-lengths and differences of frequency.

Fluorescence.			4,765	4,920	5,130	5,360	5,606	5,881	6,190
4,350	4,472	4,614	4,760	4,920	5,127	Absorption.			
$\Delta\eta$	188	206	206	198	249	251	245	250	254

This extraordinary phenomenon is to be the subject of more detailed investigations during the coming year.

Measurements of the relative intensities of the various fluorescence bands in the case of a number of uranyl salts show that the maximum of brightness does not lie in the middle of the group, but is always displaced toward the violet. The diminution in intensity in passing from band to band towards the violet is thus more rapid than the diminution towards the red on the other side of the maximum. The curves expressing this distribution of intensities are similar for the various salts and all are of a type exactly corresponding to the curve of the distribution of intensities in the broad fluorescence bands of many other substances upon which measurements have been made. It seems probable that all such broad bands are really complex and are made up of a group of narrower overlapping bands, and that in the uranyl salts we have a case in which it is possible to study these narrower bands in detail for the reason that at ordinary temperatures they overlap only to a small extent. The distribution of intensities as determined by monochromatic excitation, using successively all the ultra-violet lines of sufficient intensity in the spectrum of the mercury arc, appears (as in the cases of fluorescence hitherto investigated) to be independent of the mode of excitation. Studies of the effect of change of temperature and of dehydration of such salts as contain water of crystallization upon the position and character of the various bands of the fluorescence and absorption spectra have likewise been begun and numerous interesting and significant results have already been obtained. It is proposed in the near future to redetermine with great care the frequency differences in the overlapping regions of fluorescence and absorption, to determine the manner in which the bands observed at ordinary temperatures go over into the forms which exist at the temperature of liquid air, and to study in greater detail the effect of dehydration and the behavior of completely dehydrated salts through a wide range of temperatures.

In addition to the above experimental work, much time has been given to the preparation of a memoir to be published by the Carnegie Institution of Washington, which is to cover our investigations during the years 1903 to 1910.

During the year, Mr. H. E. Howe has continued his experiments looking to the development of a practicable and really accurate photographic method to supplant the use of the eye in the study of weak spectra and in the measurement of bands of shorter wave-lengths. In this work important advances have already been accomplished.

Dr. J. A. Veazey continued, up to the first of June, the study of kathodoluminescence which he has had in hand under our direction since 1908. Arrangements had been made under which he was to devote his time exclusively to this topic throughout the coming year. It is with great regret, however, that we have to report the death of this earnest and successful coworker. Mr. Brown, a student assistant of Dr. Veazey's during the last year, will take up and continue the work in the near future.

Mr. J. W. Hornbeak has made an exploration of the infra-red absorption spectra of certain of the uranyl salts for the purpose of determining whether the remarkable group of absorption bands existing in the visible spectrum repeats itself in some region of longer wave-lengths. His measurements, which were made with great care, using a Nichols radiometer, indicate the absence of such absorption in the infra-red spectra. It is probable, therefore, that fluorescence in the infra-red is likewise absent.

PHYSIOLOGY.

Reichert, E. T., University of Pennsylvania, Philadelphia, Pennsylvania Grant No. 700. *Study of differentiation and specificity of homologous vital substances.* (For previous report see Year Book No. 9.) $1,500

The research has been confined almost solely to the starches, with results in entire support of the hypothesis underlying the hemoglobin research. The experimental portion of the investigation will be completed within the next four or six weeks; the results of the investigation (with the exception of the final chapter and a few additions and alterations in other chapters) are typewritten and ready for the printer, and the photomicrographic work is about four-fifths done. It is expected to have the manuscript ready for presentation before the first of the coming year.

POLITICAL SCIENCE.

Rowe, L. S., University of Pennsylvania, Philadelphia, Pennsylvania. Grant No. 633. *Study of federal system of Mexico.* (For previous reports see Year Books Nos. 8, 9.) $1,500

Under a grant for the year 1910, a study of the federal system of Mexico was begun. During a stay in Mexico four chapters of this investigation were completed, covering the following:

Chapter I. The basis of the Mexican Federal system antecedents of the Constitution of 1857.
Chapter II. The provisional organic Law of 1856, and the Constitution of February 5, 1857.
Chapter III. Amendments to the Constitution of 1857.
Chapter IV. Organization of the Federal Government; Relative position of the Executive, Legislative, and Judicial Authorities.

In June 1911 Dr. Rowe returned to Mexico to continue the investigation, but for this purpose no further grant from the Institution was requested. The purpose of this second visit was to collect material for the following chapters:

Chapter V. The constitutional position of the States; Political influence of the Federal Government in the States.
Chapter VI. Constitutional guarantees in the Mexican political system.
Appendix. Documents illustrative of the Constitutional development of Mexico.

PSYCHOLOGY.

Franz, S. I., Government Hospital for the Insane, Washington, District of Columbia. Grant No. 80. *Investigation of the functions of the cerebrum.* (For previous reports see Year Books Nos. 4–9.) $1,000

During the year (September 1, 1910, to August 31, 1911) work on the cerebrum has continued. Much of that which was reported "in progress" in 1910 has been finished, and has either been published or is ready for publication.

(1) An account of a research into the mental processes of the monkey, which was performed by Dr. W. T. Shepherd under my direction, has been issued as a monograph supplement to the Psychological Review. This work was performed with monkeys which were later utilized by me in tests of the relation of the cerebrum to mental processes, and it is of special interest because methods have been employed which are also utilized for the investigation of the relation of the mental processes to different parts of the cerebrum. The conclusions formulated from this work are as follows: Monkeys learn to discriminate brightness, but take a long time for this when the stimuli have not a direct relation to the incentive for work; only a few trials are needed when the visual qualities are a part of the objects to which they naturally pay attention. Colors are discriminated with accuracy and rapidity when they are parts of the food (red, pink, yellow, and green). Three animals gave clear indications of the discrimination of different degrees of noises, and also learned to discriminate musical tones. The habits are formed rapidly if there be the double incentive of pleasant food as an inducement to a correct response and of an unpleasant stimulus to check a wrong response. From the experiments it appears that monkeys learn to inhibit recently formed habits of action with facility. As far as the evidence goes, in regard to both the formation and the inhibition of habits, monkeys are far superior to raccoons, dogs, cats, elephants, otters, and other mammals which have been investigated. Monkeys have a practical memory; they appear to show a good degree of retention, but the representative function in memory is an unknown quantity. Of the higher powers of mind, the monkey has only rudiments. He has a something which corresponds in function to ideas of a low order and which serves practical purposes. This something we call, with Hobhouse, practical ideas. Two of the monkeys learned by imitation, but six others gave no indication of imitation ability. It may be said that while monkeys may learn by imitation to a limited extent, imitation as involving ideation is a small factor in their ordinary learning process. All the tested animals appeared to reach a generalized mode of action in dealing with problems, but there seemed to be no evidence of true general notions. They have an adaptive intelligence, a lower form of reason, or a mental state inferior to true reason.

(2) During the year an article "On the association functions of the cerebrum" has been published. In this article there is given an hypothesis re-

garding the association functions of the cerebrum, which was formulated by me largely as the result of the experimental work performed in conjunction with Grant No. 80. The view expressed in that article is briefly that the frontal lobes are concerned with the motor part of the associations, while the posterior area or areas are concerned with the sensory or perceptive parts of the association. This view is in line with the facts which have been gathered by clinicians, and it helps us to understand certain facts regarding cerebral localization in man which have hitherto not been explained or understood.

(3) The principal work finished during the year was an inquiry into some of the functions of the occipital lobes. A brief account of this work is published in the American Journal of Physiology, vol. 28, pp. 308–317. The full account of these experiments is now in press and is being published as a monograph supplement to the Psychological Review.

The conclusions from all the experiments are as follows: Extirpation of the lateral parts of the occipital lobes does not interfere with color discrimination. Extirpation of the lateral parts of the so-called visual cortex in the monkey does not produce disturbances of a true visual character. The destruction of the lateral parts of the occipital cortex is followed by disturbances in coordination of movements, which are based upon the sensations from the eye and its appendages. The disturbances in coordination are not due to a lack or a loss of the true visual element, but to a lack or loss of the afferent motor elements, viz, those from the intrinsic and from the extrinsic eye-muscles. One animal in which the cortex surrounding the calcarine fissure was destroyed showed a true visual disturbance corresponding with those in man.

ZOOLOGY.

Castle, W. E., Harvard University, Cambridge, Massachusetts. Grant No. 685. *Continuation of experimental study of heredity in small mammals.* (For previous reports see Year Books Nos. 3–9.) $1,000

During the past year substantial progress has been made on the several investigations outlined in my last report.

Dr. John C. Phillips and the grantee have continued their studies on ovarian transplantation. Out of a large number of operations performed on guinea-pigs, two have proved entirely successful (in addition to the one reported last year), the grafted animal having in both cases produced young possessing color characters clearly derived from the transplanted tissue and not possessed by either ostensible parent. We have been able to find not the slightest evidence that the characters determined by the transplanted tissue had been influenced by the foreign body within which development occurred. This investigation is being continued. Its result to date affords the strongest existing experimental evidence in support of Weismann's postulate that body and germ-cells are distinct, and that characters which are inherited must have their basis in the germ-cells, characters which the parents may acquire during their lifetime not being transferred to their offspring. Publication No. 144 is based on this investigation.

In the selection experiments with rats, in which also I have been assisted by Dr. Phillips, continuous and progressive modifications are being secured of a color-pattern which behaves as a simple unit-character, mendelizing in crosses. The modifications, which are quantitative, are being obtained in opposite directions, plus and minus, in two distinct series of experiments, and there is reason to regard these modifications as permanent in nature. This conclusion supports the idea which I have presented in publications Nos. 23, 49, and 70, that mendelian unit-characters are not simple and unchangeable, like chemical atoms, but that they are subject to quantitative variation, so that by selection from among the variates new races may be gradually but surely evolved. The efficacy of selection in evolution was firmly maintained by Darwin, but has in the last decade been seriously called in question, many investigators having reached the conclusion that mutation is the only important agency in the production of new races. Our own studies, however, strongly support Darwin's view, that new races may arise in two distinct ways, (1) by cumulative selection of slight variations, and (2) by sports (or mutations).

Three other investigations, which have been in progress for some time, will probably be sufficiently advanced for publication within the next year. They relate to (1) the inheritance of color in mice (upon which subject two preliminary publications have been made this year); (2) the results of hybridizing *Cavia aperea* with the guinea-pig; and (3) blending inheritance in rabbits.

Crampton, H. E., Columbia University, New York, New York. Grant No. 563. *Study of variation, heredity, and geographical distribution of Polynesian species of Partula.* (For previous reports see Year Books Nos. 6–9.) $2,500

The work of classifying and measuring the snails is progressing, so that the final statistical results can be established. The first section of the report, dealing with certain species from Tahiti, is practically completed.

Naples Zoological Station, Naples, Italy. Grant No. 686. *Maintenance of two tables for American biologists.* (For previous reports see Year Books Nos. 2–9.) $1,000

During the last term the two Tables of the Carnegie Institution were made use of by:

Dr. O. Riddle, instructor in experimental zoology at the University of Chicago, from September 26, 1910, to March 3, 1911, and Prof. Dr. F. D. Lambert, botanist, of Tufts College, Massachusetts, from March 5 to August 10, 1911.

Both scientists have been eagerly working in the Laboratories, Dr. Riddle particularly on the formation of melanine in various animals, and Dr. Lambert (who was assisted by Mrs. Lambert) on the fructification of algæ.

LISTS OF THE NAMES OF PERSONS

ENGAGED IN THE

VARIOUS ACTIVITIES

OF THE

CARNEGIE INSTITUTION OF WASHINGTON

From the Time of its Organization, in 1902,
Until November 30, 1911.

1.—Names of Persons Engaged in Investigation under the Departments of the Carnegie Institution of Washington from its Organization until November 1911.

Department of Botanical Research.

*Cannon, William A.
Kirkwood, J. E.
Knox, Alice A.
Livingston, Burton E.
*MacDougal, Daniel T.
*Shreve, Forrest
Spalding, Volney M.
*Spoehr, H. A.
*Sykes, G.

Department of Economics and Sociology.

(Board of Collaborators.)

*Butterfield, Kenyon L.
*Clark, Victor S.
*Commons, John R.
Day, Clive
*Dewey, Davis R.
*Farnam, Henry W.
*Gardner, Henry B.
*Jenks, J. W.
*Johnson, Emory R.
*Meyer, B. H.
North, S. N. D.
*Parker, Edward W.
Ripley, W. Z.
Seligman, E. R. A.
*Stone, Alfred H.
*Willcox, Walter F.
Wright, Carroll D.

Department of Experimental Evolution.

*Banta, Arthur M.
*Davenport, Charles B.
*Goodale, Hubert D.
*Gortner, R. A.
*Harris, J. Arthur
Johnson, Roswell H.
Lutz, Anne M.
Lutz, Frank E.
Riddle, Oscar
Rose, R. Catlin
*Shull, George H.
Stephenson, J. C.
Transeau, E. N.

Geophysical Laboratory.

*Adams, L. H.
*Allen, Eugene T.
Clement, J. K.
*Crenshaw, J. L.
*Day, Arthur L.
*Fenner, C. N.
*Johnston, John
Larsen, Jr., E. S.
*Merwin, H. E.
*Rankin, G. A.
*Shepherd, E. S.
*Sosman, Robert B.
*White, Walter P.
*Wright, Fred. E.

Department of Historical Research.

Bowman, H. M.
*Burnett, E. C.
*Davenport, Frances G.
*Donnan, Elizabeth P.
Fox, J. S.
Griffin, Mary F.
*Jameson, J. Franklin
Jernegan, M. W.
*Leland, Waldo G.
Lewis, E. D.
Lincoln, C. H.
McLaughlin, Andrew C.
*Parker, D. W.
Russell, J. H.
Slade, W. A.
Stephens, F. F.
*Stock, L. F.
Thompson, Laura
Van Tyne, Claude H.

Department of Marine Biology.

*Longley, William H.
*Mayer, Alfred G.

Department of Meridian Astrometry.

*Benway, Beulah L.
*Boss, Benjamin
*Boss, Lewis
*Buffum, Grace I.
*Clark, Livia C.
Delavan, P. T.
*Dyer, Mabel A.
Fair, J. N.
*Fowler, Lillian V.
*Grant, Sherwood B.
Hunt, William
*Jenkins, Heroy
*Jennings, Mary C.
*MacNeill, Fannie L.
Mearns, Louis Z.
*Raymond, Harry
*Roy, Arthur J.
Roy, M. I.
Sanford, R. F.
Tucker, R. H.
*Varnum, William B.
*Zimmer, Meade L.

Mount Wilson Solar Observatory.

*Adams, Walter S.
*Babcock, Harold D.
*Burwell, Cora G.
*Ellerman, Ferdinand
*Ensign, Inez A.
*Fath, Edward A.
Griffin, Clementina de F.
Haines, Jessie M.
*Hale, George E.
*King, Arthur S.
*Kohlschütter, Arnold
*Lasby, Jennie B.
Olmsted, Charles M.
Palmer, H. K.
*Pease, Francis G.
*Renner, Martha
Ritchey, G. W.
*Seares, F. H.
*Sheldon, M. Wanda
*Smith, Ruth E.
*St. John, Charles E.
*Ware, Louise
Waterman, E. Phoebe
Way, W. I.
Wickham, Lillian

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* Indicates members of the present staff.

NUTRITION LABORATORY.

*Arndt, Kurt H.
*Babcock, Elizabeth B.
*Benedict, Francis G.
Carney, R. I.
*Carpenter, Thorne M.
Courtney, Angelia M.
*Currie, J. J.
Emery, Albert G.
*Emmes, L. E.
*Fitzgerald, J. E.
Glasier, A. F.
*Hayes, Elliott W.
*Higgins, Harold L.
*Holway, Claude H.
*Johnson, Alice
*Jones, Paul F.
*Kallen, Frances E.
Metcalf, E. H.
Murray, F. J.
*Peters, A. W.
Riche, Jesse A.
Sherman, Hope
Slack, Edgar P.
Stevens, H. A.

DEPARTMENT OF TERRESTRIAL MAGNETISM.

*Ault, J. P.
*Bauer, L. A.
Bauer, W. C.
Bowen, E. H.
Burbank, J. E.
Cady, W. G.
Carroll, C. R.
Craft, C. C.
Dike, P. H.
*Edmonds, H. M. W.
*Edmunds, C. K.
Egbert, J. H.
*Fisk, H. W.
*Fleming, J. A.
*Frary, H. D.
Fuson, C. G.
Heimbrod, G.
Homrighaus, A. H.
Hosmer, G. L.
*Johnston, H. F.
*Kidson, E.
Martyn, H. E.
McKelden, Alice M.
Pearson, J. C.
*Peters, W. J.
Peterson, G.
Pratt, J. F.
*Sligh, W. H.
Smith, C. D.
Smith, D. F.
Sowers, D. C.
*Stewart, C. C.
Swett, P. N.
Tafel, R. R.
Tamura, S. T.
*Webb, E. N.
Wernicke, P.
Whitney, P. C.
*Widmer, J. Adolf

2.—LIST OF NAMES OF INVESTIGATORS AND ASSOCIATES, WITH SUBJECT, TIME, AND PLACE OF RESEARCH.

This list will be found to include investigators and associates who have been actively engaged in carrying on researches under the auspices of the Institution, and also the names of authors and co-authors of publications issued by the Institution.

Abbot, C. G. 1905–. Astrophysics. Mount Wilson Solar Observatory.
Abel, John J. 1903–5. Physiological chemistry. Johns Hopkins University.
Abetti, Giorgio. 1909. Astronomy. Mount Wilson Solar Observatory.
Acree, S. F. 1904–. Chemistry. Johns Hopkins University.
Adams, E. D. 1904. History. Leland Stanford Jr. University.
Adams, Frank D. 1902–. Geophysics. McGill University.
Allen, Gordon. 1905–6. Architecture. Athens.
Allison, W. H. 1908–10. History. United States.
Ames, J. S. 1904–5. Physics. Johns Hopkins University.
Anderson, John A. 1909. Chemistry. Johns Hopkins University.
Andrews, C. M. 1905–11. History. England.
Armstrong, Henry H. 1909–10. Classical archeology. Italy.
Atwater, W. O. 1902–5. Nutrition. Wesleyan University.
Baird, J. W. 1903–4. Psychology. Cornell University.
Ballou, Susan H. 1905–6. Classical archeology. Italy.
Bancroft, Wilder D. 1902–. Physical chemistry. Cornell University.
Bandelier, A. F. 1911–. Archeology. New York, N. Y.; Mexico.
Barker, G. F. 1904. Physics. Washington, D. C.
Barnard, E. E. 1905, 1911. Astronomy. Mount Wilson Solar Observatory.
Barnett, S. J. 1904–5. Physics. Leland Stanford Jr. University.
Barus, Carl. 1905–. Physics. Brown University.
Baskerville, Charles. 1904–5. Chemistry. University of North Carolina.
Bate, John P. 1910–. International law. England.
Baxter, Gregory P. 1904–. Chemistry. Harvard University.
Beattie, J. C. 1908–10. Terrestrial magnetism. Africa.
Becker, George F. 1904, 1906–10. Geophysics. U. S. Geological Survey.
Behr, G. E. 1906. Chemistry. Harvard University.
Benton, J. R. 1904–5. Geophysics. U. S. Geological Survey.
Bjerknes, V. 1906–. Meteorology. Stockholm and Christiania.
Blackwelder, Eliot. 1903–4. Geology. China.
Blake, W. P. 1908–10. Geology. Desert Botanical Laboratory.
Blakeslee, Alfred F. 1904–6. Botany. Germany.

Bolton, Herbert E. 1907–11. History. Mexico.
Bragg, Charlotte. 1908. Chemistry. Nutrition Laboratory.
Branner, J. C. 1906–7. Geology. California.
Breitenbecker, J. B. 1910–11. Biology. Desert Botanical Laboratory.
Brierly, J. Leslie. 1910–11. International law. England.
Brigham, William T. 1906–. Anthropology. Hawaii.
Brooks, W. K. 1905, 1906. Zoology. Tortugas Laboratory.
Brown, Amos P. 1904–8. Mineralogy. University of Pennsylvania.
Brown, Ernest W. 1911. Air vitiation. Nutrition Laboratory.
Brown, J. G. 1910–11. Botany. Desert Botanical Laboratory.
Brown, W. H. 1910–11. Botany. Desert Botanical Laboratory.
Brückmann, W. 1905–6. Terrestrial magnetism. Potsdam, Germany.
Burbank, Luther. 1905–9. Plant evolution. Santa Rosa, California.
Burckhalter, Charles. 1906–7. Astronomy. California.
Burgess, Charles F. 1905–9. Electrochemistry. University of Wisconsin.
Burnham, S. W. 1906. Astronomy. Yerkes Observatory.
Caldwell, J. S. 1911. Botany. Desert Botanical Laboratory.
Campbell, D. H. 1911. Botany. Leland Stanford Jr. University.
Campbell, William. 1904–5. Metallurgy. Columbia University.
Campbell, W. W. 1903–9. Astronomy. Lick Observatory.
Cardiff, Ira D. 1909. Botany. Desert Botanical Laboratory.
Carhart, Henry S. 1904–5. Physics. University of Michigan.
Cary, L. R. 1910–11. Zoology. Tortugas Laboratory.
Case, E. C. 1903–5, 1909. Paleontology. State Normal School, Milwaukee, Wis.; University of Michigan.
Castle, W. E. 1904–. Zoology. Station for Experimental Evolution; Harvard University.
Cathcart, E. P. 1911. Physiology. Nutrition Laboratory.
Cattell, J. McKeen. 1903–4. Biographical directory. Columbia University.
Chamberlain, C. W. 1909. Physics. Mount Wilson Solar Observatory.
Chamberlin, R. T. 1908. Geology. University of Chicago.
Chamberlin, T. C. 1903–. Geology. University of Chicago.
Chapman, Frank M. 1907. Ornithology. Tortugas Laboratory.
Chittenden, Russell H. 1904–7. Physiological chemistry. Yale University.
Chrétien, Henri. 1910. Astronomy. Mount Wilson Solar Observatory.
Churchill, William. 1911. Philology. New York, N. Y.
Clawson, A. B. 1907. Zoology. University of Michigan.
Coble, A. B. 1903–4. Mathematics. University of Missouri; Johns Hopkins University.
Coblentz, W. W. 1903–8, 1911. Physics. Cornell University; Bureau of Standards.
Cohnheim, Otto. 1910. Metabolism. Nutrition Laboratory.
Coker, E. G. 1906. Geophysics. McGill University.
Cole, Leon J. 1906. Zoology. Tortugas Laboratory.
Conard, Henry S. 1903. Botany. University of Pennsylvania; Europe.
Conklin, Edwin G. 1905, 1907. Cytology. Tortugas Laboratory; Bahamas; Woods Hole, Mass.
Coville, F. V. 1902–5. Botany. Desert Botanical Laboratory.
Cowles, R. P. 1905, 1906, 1908, 1909. Œcology, reactions to stimuli. Tortugas Laboratory.
Crampton, Henry E. 1903–9. Zoology. Station for Experimental Evolution; Islands of S. Pacific; Columbia University.
Crew, Henry. 1903–4. Physics. Northwestern University.
Dahlgren, Ulric. 1906, 1911. Histology. Tortugas Laboratory.
Davidson, George. 1906–7. Geography and geodesy. California.
Davis, Herman S. 1903–5. Astronomy. International Latitude Observatory.
Davis, W. M. 1903–4. Physical geography. China.
Dean, Bashford. 1906. Zoology. Columbia University.
Decker, F. F. 1910. Mathematics. Syracuse University.
de Lapradelle, A. G. 1910–. International law. France.
Dickson, L. E. 1904–5. Mathematics. University of Chicago.
Dinsmoor, William B. 1907–. Architecture. Athens.
Dodd, Walter F. 1907–8. History. Washington, D. C.
Donaldson, H. H. 1910. Neurology. Station for Experimental Evolution.
Dorsey, George A. 1903–7. Anthropology. Field Museum of Natural History.
Drew, G. Harold. 1911. Geology. Tortugas Laboratory; Jamaica.

Duerden, J. E. 1903–7. Biology. University of Michigan; Rhodes University, South Africa.
Duerst, J. U. 1906. Archeology. Turkestan.
Durand, W. F. 1903–4. Marine engineering. Cornell University.
Dyar, Harrison G. 1903–11. Entomology. Washington, D. C.
Eames, Wilberforce. 1906–8. Bibliography. New York Public Library.
Edmondson, C. H. 1906. Zoology. Tortugas Laboratory.
Edsall, David L. 1911. Physiology. Nutrition Laboratory.
Eigenmann, Carl H. 1903–4. Zoology. Indiana University; Cuba.
Elster, J. 1904–5. Atmospheric electricity. Palma, Majorca, Spain.
Enteman, Wilhelmina M. 1904. Biology. New Mexico Normal University.
Falta, W. 1908. Diabetes. Nutrition Laboratory.
Farlow, W. G. 1905. Botany. Harvard University.
Farrar, Clarence B. 1905–6. Psychology. Sheppard and Enoch Pratt Hospital, Baltimore, Md.
Fenwick, Charles G. 1910–. International law. Baltimore, Maryland.
Ferguson, W. S. 1906–7. Grecian history. Harvard University; Europe.
Fink, Bruce. 1908. Botany. Desert Botanical Laboratory.
Fish, Carl R. 1908–9. History. Italy.
Fletcher, Robert. 1903–11. Bibliography. Surgeon General's Office, Washington, D. C.
Flexner, Simon. 1902–3. Physiology. University of Pennsylvania.
Flügel, Ewald. 1904–8. Philology. Germany; Leland Stanford Jr. University.
Forbes, Alexander. 1906. Zoology. Harvard University.
Forbes, G. S. 1906. Chemistry. Harvard University.
Forbes, R. H. 1907. Chemistry. Desert Botanical Laboratory.
Ford, Worthington C. 1903. History. Washington, D. C.
Fox, Philip. 1908. Astronomy. Yerkes Observatory.
Franklin, W. S. 1906. Physics. Lehigh University.
Franz, S. I. 1903–11. Psychology. McLean Hospital; Government Hospital for Insane.
Free, E. E. 1909–11. Physics. Desert Botanical Laboratory.
Freudenberger, L. A. 1906. Physics. Delaware College.
Frost, Edwin B. 1907. Astrophysics. Yerkes Observatory.
Fryer, Charles E. 1911. History. England.
Furness, Caroline E. 1905. Astronomy. Vassar College.
Gale, Henry G. 1909–. Physics. Mount Wilson Solar Observatory.
Gamgee, Arthur. 1903–6. Nutrition. Europe.
Garrison, Fielding H. 1903–. Bibliography. Surgeon General's Office, Washington, D. C.
Geitel, H. 1904–5. Atmospheric electricity. Palma, Majorca, Spain.
Gies, William J. 1908. Biological chemistry. Columbia University.
Gilbert, G. K. 1904, 1906–7. Geology. Georgia; California.
Gilmore, L. H. 1905. Physics. Mount Wilson Solar Observatory.
Goldthwait, Joel E. 1907–8. Chemistry. Boston, Mass.
Gomberg, Moses. 1904–5. Chemistry. University of Michigan.
Goss, W. F. M. 1904–8. Steam engineering. Purdue University; University of Illinois.
Gulick, John T. 1905. Biology. Hawaii.
Guthrie, C. C. 1908. Physiology. Station for Experimental Evolution.
Hall, G. Stanley. 1903–4. Psychology. Clark University.
Hargitt, Charles W. 1905, 1910. Zoology. Woods Hole, Mass.; Tortugas Laboratory.
Harmon, Morris A. 1906–7. Classical archeology. Italy.
Harms, F. 1905. Atmospheric electricity. Palma, Majorca, Spain.
Harper, R. A. 1905. Botany. University of Wisconsin.
Hartmeyer, Robert. 1907. Systematic biology. Tortugas Laboratory.
Harvey, E. Newton. 1909, 1910–11. Physiology. Tortugas Laboratory.
Haskins, Charles H. 1905–8. History. Harvard University; Europe.
Hasse, Adelaide R. 1906–. Bibliography. Archives of States.
Hay, O. P. 1903–7. Paleontology. American Museum of Natural History.
Hempl, George. 1905–. Philology. University of Michigan; Leland Stanford Jr. University.
Hill, G. W. 1905–7. Mathematical astronomy. West Nyack, N. Y.
Hill, Roscoe R. 1911–. History. Spain.
Hindhede, M. 1910. Diabetes. Nutrition Laboratory.
Hirth, Friedrich. 1907. Language. Columbia University.

Hodell, Charles W. 1907–8. Literature. Goucher College.
Hodge, C. F. 1907. Biology. Clark University.
Holland, Thomas E. 1910–. International law. Oxford University.
Holmes, W. H. 1903. Anthropology. Bureau of American Ethnology.
Homans, John. 1910–11. Physiology. Nutrition Laboratory.
Hooker, Davenport. 1905, 1907, 1908. Œcology. Tortugas Laboratory.
Howard, L. O. 1903–11. Entomology. U. S. Dept. Agriculture; United States; Mexico; Canada.
Howe, H. M. 1907–. Metallurgy. Columbia University.
Hoyt, W. D. 1909–10. Botany. Desert Botanical Laboratory.
Huntington, Ellsworth. 1903–4, 1910–. Botany. Desert Botanical Laboratory; Turkestan.
Iddings, Joseph P. 1904–5. Petrology. U. S. Geological Survey.
Jacobs, Merkel H. 1911. Physiology. Tortugas Laboratory.
Jacomini, C. 1904–. Engineer. Mount Wilson Solar Observatory.
Jaeger, F. M. 1910–11. Geophysics. Geophysical Laboratory.
Jennings, H. S. 1903–5. Zoology. University of Michigan; University of Pennsylvania; Station for Experimental Evolution; Tortugas Laboratory; Naples Zoological Station.
Johnson, A. C. 1910–11. Archeology. Greece.
Johnson, Dora. 1911. Archeology. Rome.
Jones, Harry C. 1903–. Physical chemistry. Johns Hopkins University.
Jones, William. 1904–9. Anthropology. Indian tribes in Central United States.
Jordan, H. E. 1907. Histology. Tortugas Laboratory.
Jörgensen, E. 1910. Systematic biology. Tortugas Laboratory.
Joslin, Elliott P. 1908–11. Diabetes. Nutrition Laboratory.
Julius, W. H. 1907. Physics. Mount Wilson Solar Observatory.
Kapteyn, J. C. 1908–. Astronomy. Mount Wilson Solar Observatory.
Kellner, Carl. 1905, 1906, 1907. Systematic biology. Tortugas Laboratory.
Knab, Frederick. 1903–11. Entomology. Washington, D. C.
Krogh, August, 1908. Metabolism. Greenland.
Kunz, George F. 1902–3. Mineralogy. New York, N. Y.
Lawson, Andrew C. 1906–7. Geology. California.
Learned, Marion D. 1909–10. History. Germany.
Lehmer, D. N. 1904–9, 1911–. Mathematics. University of California.
Leuschner, A. O. 1906–7. Astronomy. California.
Lewis, E. P. 1904–5. Experimental physics. University of California.
Lillie, Ralph S. 1904–5. Physiology. University of Nebraska; Naples Zoological Station.
Linton, Edwin. 1906, 1907, 1908–. Systematic biology. Tortugas Laboratory.
Littlehales, G. W. 1905–6. Terrestrial magnetism. Washington, D. C.
Livingston, B. E. 1904–. Soil physics; botany. Desert Botanical Laboratory.
Livingston, Mrs. G. J. 1906–7. Physics. Desert Botanical Laboratory.
Lloyd, F. E. 1904–6, 1910–11. Botany. Desert Botanical Laboratory.
Lockwood, Dean P. 1908–9. Classical archeology. Italy.
Loeb, Leo. 1903–5, 1907–9. Physiology. Woods Hole, Mass.; University of Pennsylvania.
Loew, Elias A. 1907–8, 1909–. Classical archeology. Italy.
Long, Joseph A. 1911. Zoology. Harvard University.
Louderback, George D. 1903–5. Geology. University of California.
Lows, Kristian. 1909. Astronomy. Mount Wilson Solar Observatory.
Ludwig, Albert. 1908–9. Geophysics. Geophysical Laboratory.
Lum, Elizabeth S. 1910. Embryology. Station for Experimental Evolution.
Lunn, A. C. 1909. Mathematics. University of Chicago.
MacCurdy, H. 1907. Zoology. Harvard University.
MacMillan, W. D. 1909. Mathematics. University of Chicago.
Maguire, John D. 1909–. International law. Washington, D. C.
Manning, W. R. 1908–10. History. Washington, D. C.
Mark, E. L. 1906–10. Zoology. Harvard University.
Mascart, E. 1904–8. Terrestrial magnetism and atmospheric electricity. France.
Mast, S. O. 1910. Reactions to stimuli. Tortugas Laboratory.
McCay, D. 1908–10. Metabolism. Calcutta, India.
McClendon, J. F. 1904, 1908, 1910. Physiology. Woods Hole, Mass.; Tortugas Laboratory.
Meek, S. E. 1909. Ichthyology. Tortugas Laboratory.

Mendel, Lafayette B. 1905–6. Physiological chemistry. Yale University.
Merritt, Ernest. 1905–6, 1909–. Experimental physics. Cornell University.
Michelson, A. A. 1903–4. Physics. University of Chicago.
Moenkhaus, W. J. 1904–6. Physiology. Station for Experimental Evolution.
Morley, F. 1909–. Mathematics. Johns Hopkins University.
Morrison, J. T. 1908–9. Terrestrial magnetism. Africa.
Morse, Albert P. 1903–5. Zoology. Southern States.
Morse, H. N. 1903–. Chemistry. Johns Hopkins University.
Mottier, David M. 1904. Botany. Indiana University.
Moulton, F. R. 1909–. Mathematical physics. University of Chicago.
Müller, W. Max. 1904–10. Archeology. Egypt.
Murlin, J. R. 1909. Chemistry. Nutrition Laboratory.
Newcomb, Simon. 1903–9. Astronomy. Washington, D. C.
Nichols, E. F. 1908–9. Experimental physics. Mount Wilson Solar Observatory.
Nichols, Edward L. 1905–6, 1909–. Experimental physics. Cornell University.
Nippoldt, A. 1905–6. Terrestrial magnetism. Potsdam, Germany.
Noguchi, Hideyo. 1903–8. Physiology. University of Pennsylvania.
Noyes, Arthur A. 1903–. Chemistry. Massachusetts Institute of Technology.
Oddone, E. 1905. Terrestrial magnetism; atmospheric electricity. Tripoli, Africa.
Olive, Edgar W. 1903–5. Botany. Germany; University of Wisconsin.
Osborne, Thomas B. 1904–. Chemistry. Connecticut Agricultural Experiment Station.
Osburn, Raymond C. 1908. Systematic zoology. Tortugas Laboratory.
Osgood, H. L. 1911–. History. Columbia University.
Palazzo, L. 1905. Terrestrial magnetism; atmospheric electricity. Tripoli, Africa.
Parkhurst, John A. 1906. Astronomy. Yerkes Observatory.
Paullin, Charles O. 1910–11. History. England.
Paxson, Frederick L. 1910. History. England.
Pearl, Raymond. 1904–6. Biology. University of Michigan; University of Pennsylvania; England; Germany; Naples Zoological Station.
Peirce, G. J. 1910–11. Botany. California.
Pender, Harold. 1902–3. Electrical engineering. Paris, France.
Pérez, Luis M. 1905–6. History. Cuba.
Perkins, H. F. 1903–5. Zoology. Tortugas Laboratory; University of Vermont.
Perrine, C. D. 1910. Astronomy. Lick Observatory.
Phillips, J. C. 1911. Zoology. Harvard University.
Phillips, Ulrich B. 1904–6. History. University of Wisconsin.
Pratt, Henry S. 1909, 1910. Morphology. Tortugas Laboratory.
Pratt, Joseph H. 1911. Animal metabolism. Nutrition Laboratory.
Pumpelly, Raphael. 1903–9. Archeology. Turkestan.
Pumpelly, R. W. 1904–6. Archeology. Turkestan.
Putnam, Herbert. 1903–7. Bibliography. Washington, D. C.
Reichert, Edward. 1904–. Physiology. University of Pennsylvania.
Reid, Harry Fielding. 1906–7. Geophysics. California.
Reighard, Jacob. 1905, 1907. Reactions to stimuli. Tortugas Laboratory.
Reinke, E. E. 1911. Zoology. Tortugas Laboratory; Jamaica.
Richards, H. M. 1911. Botany. Desert Botanical Laboratory.
Richards, Theodore W. 1903–. Chemistry. Harvard University.
Robertson, James A. 1909–10. History. United States.
Rose, J. N. 1908–10. Botany. Desert Botanical Laboratory.
Ross, Frank E. 1903–9. Astronomy. Washington, D. C.
Ross, W. H. 1909–11. Chemistry. Desert Botanical Laboratory.
Roth, Paul. 1911. Respiratory exchange. Nutrition Laboratory.
Rowe, Allan W. 1908. Chemistry. Nutrition Laboratory; Harvard University.
Rowe, Leo S. 1906–. Political science. Mexico; Argentina.
Rücker, Sir Arthur. 1904–. Terrestrial magnetism; atmospheric electricity. Tripoli, Africa.
Russell, Henry N. 1903–5. Astronomy. Princeton University; Cambridge University.
Sandström, J. W. 1906–8. Meteorology. University of Stockholm.
Sargent, R. H. 1903–4. Geology. China.
Schlesinger, Frank. 1903–5, 1907. Astronomy. Yerkes Observatory; Allegheny Observatory.
Schmidt, Adolf. 1904–10. Terrestrial magnetism. Potsdam, Germany.
Schmidt, Hubert. 1904. Archeology. Turkestan.
Schuster, Arthur. 1904. Cosmical physics. Manchester, England.

Scott, George W. 1903. Law. Philadelphia, Pa.; Washington, D. C.; Europe.
Scott, James Brown. 1909–. International law. Washington, D. C.
Scripture, E. W. 1903–6. Phonetics. Yale University; Europe.
Shaw, James B. 1907. Mathematics. James Millikin University.
Shepherd, Wm. R. 1905–7. History. Spain.
Shreve, Mrs. E. B. 1911. Botany. Desert Botanical Laboratory.
Slichter, C. S. 1909. Mathematics. University of Wisconsin.
Small, John K. 1904–5. Botany. New York Botanical Garden.
Smith, Albert. 1911. Consulting engineer. Mount Wilson Solar Observatory.
Smith, Erwin F. 1905–. Bacteriology. Washington, D. C.
Smith, H. M. 1910. Respiratory exchange. Nutrition Laboratory.
Sommer, H. Oskar. 1906–. Literature. England.
Spalding, Mrs. E. S. 1904–10. Botany. Desert Botanical Laboratory.
Spooner, L. H. 1911. Animal metabolism. Nutrition Laboratory.
Stager, Henry W. 1911. Mathematics. Fresno, California.
Stanwood, Frederic A. 1908–11. Diabetes. Harvard Medical School.
Stevens, Gorham P. 1904–5. Architecture. Athens.
Stevens, Nettie M. 1904, 1905. Biology. Woods Hole, Mass.; Station for Experimental Evolution; Bryn Mawr College.
Stieglitz, Julius. 1909. Chemistry. University of Chicago.
Stockard, Charles R. 1907, 1908, 1909, 1910. Regeneration, œcology. Tortugas Laboratory; Naples Zoological Station.
Stromsten, Frank A. 1907, 1910. Embryology. Tortugas Laboratory.
Strong, W. W. 1910. Physics. Johns Hopkins University.
Stull, W. N. 1903. Chemistry. Harvard University.
Talbot, Fritz B. 1911. Infant metabolism. Nutrition Laboratory.
Tennent, D. H. 1909, 1910. Hybridity. Tortugas Laboratory.
Thompson, J. David. 1903–7. Bibliography. Washington, D. C.
Thornber, J. J. 1906–8. Botany. Desert Botanical Laboratory.
Tolman, C. F. 1906–8. Geology. Desert Botanical Laboratory.
Tower, W. L. 1904–. Biology, evolution. University of Chicago; Mexico; Desert Botanical Laboratory; Tortugas Laboratory.
Treadwell, Aaron L. 1904, 1909, 1910. Zoology. Woods Hole, Mass.; Tortugas Laboratory.
Uhler, H. S. 1907. Physics. Johns Hopkins University.
Upton, Winslow. 1905. Astronomy. Mount Wilson Solar Observatory.
Vail, Anna M. 1904–5. Botany. New York Botanical Garden.
Van Buren, Albert W. 1905–6. Classical archeology. Italy.
Van Deman, Esther B. 1906–. Classical archeology. Italy.
Van Orstrand, C. E. 1904, 1906–10. Geophysics. U. S. Geological Survey; Geophysical Laboratory.
Vaughan, T. Wayland. 1908–. Geology, zoology. Bahamas; Florida Keys; Tortugas Laboratory.
von Bar, Ludwig. 1910. International law. Germany.
Wallace, W. Seward. 1908. Marine biology. Tortugas Laboratory.
Ward, Lester F. 1906. Paleobotany. Brown University.
Ward, William Hayes. 1903–9. Archeology. United States; Europe.
Washington, Henry S. 1904–6. Petrology. Southern Europe; Locust, N. J.
Watson, John B. 1907, 1910. Œcology. Tortugas Laboratory.
Wells, Roger C. 1905. Chemistry. Harvard University.
Westlake, John. 1910–11. International law. England.
Whitney, Mary W. 1903–4. Astronomy. Vassar College.
Wieland, G. R. 1903–. Paleobotany. Mexico; Yale University.
Wilczynski, E. J. 1903–4. Mathematics. Germany; University of California.
Willard, H. H. 1910. Chemistry. Harvard University.
Williams, H. B. 1909. Chemistry. Nutrition Laboratory.
Willis, Bailey. 1903–8. Geology. Asia; Washington, D. C.
Wilson, E. B. 1903–8. Biology. Woods Hole, Mass.; Naples Zoological Station; Southwestern United States.
Wood, Henry D. 1906–8. Architecture. Italy.
Wood, R. W. 1903–5. Experimental physics. Johns Hopkins University.
Yatsu, Naohide. 1905–6. Biology. Columbia University; Harpswell Laboratory; Naples Zoological Station.
Zeleny, Charles. 1906. Regeneration. Tortugas Laboratory.
Zwierlein, Frederick J. 1911. History. Quebec.

3.—List of Advisors, Collaborators, Grantees, and Assistants in Research Not Mentioned in Previous Lists, Together with Administrative Officers, Clerical Assistants, Mechanicians, and All Others Connected with the Carnegie Institution of Washington from its Organization to November 1911.

The list has been prepared from available records procured from many sources. If omissions or inaccuracies are observed, notification of such information will be appreciated by the Institution. (a) indicates confidential advisors or members of advisory committees, 1902–03.

Abbe, Cleveland (a)
Abbott, Edith
Abel, Anna H.
Ackerman, P. C.
Adams, A. D.
Adams, Chas. F. (a)
Adams, Henry C.
Adler, Cyrus (a)
Adriance, W. M.
Agerton, Maude
Albord, Frederick
Aldrich, Louis B.
Alexander, W. H.
Allemann, Albert
Allen, Charles E.
Allen, Frank
Allen, Frank B.
Allen, George H.
Allen, Leah
Alling, Miss H. L.
Allison, Emily M.
Alsberg, Carl L.
Ambler, C. H.
Anderson, G. P.
Anderson, J. B.
Anderson, Lewis
Anderson, Robert
Andrews, Frank M.
Andrews, J. B.
Aronovici, Carol
Armstrong, H. M.
Arnold, C. R.
Askew, Frances
Aston, James
Atwater, Miss H. W.
Atwood, G. A.
Austin, Charles B.
Austin, Charles F.
Ayers, Alden F.
Ayers, S. A.
Ayres, H. D.
Babine, Alexis V.
Backus, Charles S.
Bailey, W. L.
Bain, Samuel M.
Bair, Joseph H.
Baird, Benjamin A.
Baker, Marcus
Baker, O. E.
Baker, R. H.
Balch, Miss E. G.
Baldwin, A. H.
Baldwin, A. L.
Baldwin, F. Spencer
Baldwin, J. Mark (a)
Ball, S. H.
Bam, D.
Banks, Enoch M.
Barkentin, G. S.
Barnard, J. Lynn
Barnes, T. A.
Barnett, George E.
Barnum, Charlotte C.
Barnum, William
Barnum, William H.
Barrows, W. N.
Barry, Frederick
Bartlett, Frank S.
Bartlett, H. T.
Barus, Maxwell
Bassett, H. P.
Bates, Isabelle M.
Baxter, Walter F.
Beal, William O.
Beall, Sarah
Bechtel, G. Gerald
Beck, Washington
Bedford, Scott E. W.
Beehler, Emma L.
Bellamy, Edith
Bengtson, Ida A.
Bernhoff, John
Bessey, Ernst A.
Bigelow, H. E.
Bigelow, M. A.
Biggar, H. P.
Billberry, George E.
Bingham, E. C.
Bishop, Avard L.
Black, O. F.
Black, W. W.
Blackmar, F. W.
Blair, Andrew A.
Bliss, Frederick J.
Blume, S.
Blumer, J. C.
Boas, Franz (a)
Boeckh, Richard
Bogart, Ernest L.
Bolles, M. N.
Bond, Jr., Beverley W.
Bonnet, Jr., Frederic
Bonser, Thomas A.
Boring, Alice M.
Böttger, William
Bovee, B. R.
Bowditch, H. P. (a)
Bowen, Francis
Bowen, N. L.
Bowes, Catharine
Boyd, W. K.
Boyle, James E.
Brace, Edith M.
Bradford, Roy
Bradley, H. C.
Bradway, James W.
Brant, Laura C.
Brasch, F. E.
Brauner, Bruno
Brautlecht, C. A.
Bray, William C.
Bray, W. L.
Breckinridge, Sophonisba
Breen, Susie
Breslin, Sadie E.
Bridgman, P. W.
Brink, F. N.
Briton, W. E.
Britton, N. L. (a)
Brownson, J. B.
Brooks, Hildegarde
Brough, C. H.
Brown, Orville H.
Brown, T. C.
Browne, Charles E.
Brownell, Edith
Brownson, H. G.
Bruel, Francois
Brues, C. J.
Brunel, R. F.
Bryan, Walter
Buchanan, Daniel
Buchanan, Herbert E.
Buck, Thomas
Buck, Solon J.
Buckley, William
Bunting, Martha
Burgess, Laurie L.
Burke, William M.
Burklin, George
Burnham, Ernest
Burns, George P.
Burns, Keivin
Burr, Mary J.
Burr, William H. (a)
Burr, W. W.
Burris, M. A.
Bursch, Frederick C.
Burton, Ada I.

Busck, August
Byall, J. Bruce
Byrd, James R.
Campbell, Archibald
Campbell, Robert
Cance, A. E.
Carey, L. R,
Carlson, Anton J.
Carpenter, Ford A.
Carpenter, J. L.
Carroll, C. G.
Carter, Mrs. J.
Carver, T. N.
Cash, G.
Chaddock, Robert E.
Chamberlin, B. D.
Champreux, A. J.
Chandler, J.
Chapin, Harold C.
Chapman, James
Chapman, J. W.
Charlton, G. A.
Child, Clement D.
Christman, Erwin S.
Chrysler, M. A.
Church, Jr., J. E.
Clapp, Cornelia M.
Clapp, L. H.
Clark, C. F.
Clark, C. P.
Clark, Elizabeth E.
Clark, John B. (a)
Clark, Margaret
Clark, Mary J.
Clark, W. M.
Clarke, John M.
Clarke, Frank W.
Clarke, Latham
Clausen, M.
Clements, F. E.
Cleveland, F. A.
Closson, Oliver E.
Closstham, E. C.
Coady, Martin
Cobb, Victor
Coffin, Fletcher B.
Coffin, T. H.
Coghill, G. E.
Colbeth, Philena A.
Colby, H. E.
Colby, William E.
Cole, J. R.
Coles, Frank
Collins, W. E.
Colson, H. R.
Colton, H. S.
Cone, Lee H.
Conner, J. R.
Conway, Jr., Thomas
Cook, Frances M.
Cook, M. T.
Cook, O. F.
Cooke, Elizabeth
Coolidge, Mary R.
Coolidge, W. D.
Cooper, Herman C.
Copeland, Manton
Coquillet, D. W.
Coulter, John L.
Courcier, John F.
Coutiere, Henri
Cowles, H. C.
Crafer, Thomas
Craig, Jr., James
Craig, Lucy
Crane, Walter R.
Crandall, Rodine
Crook, J. W.
Cross, Ira B.
Curry, B. E.
Curtiss, R. H.
Cushman, Florence
Daggett, Stuart
Dales, Benton
Dalke, Diedrich
Dalton, James
Dalton, John S.
Darby, Fred.
Darling, Annie N.
Davenport, Mrs. C. B.
Davis, Beatrice M.
Davis, Bradley M.
Davis, Edward H.
Davis, Jasper P.
Dawson, Edgar M.
Day, David T.
Dean, Arthur L.
DeLong, B. H.
De Majo, Mony
DeMello, Carlos
Denham, Jr., Robert N.
De Raasloff, H.
Dennis, L. M.
Derfendorf, A. R.
Desha, L. J.
Detlefsen, John
Devik, Olaf
Dickinson, H. C.
Dieserud, Juul
Dinsmore, S. C.
Diserens, Paul
Dobbin, Emily E.
Dobrowolski, A. F.
Dodge, C. W.
Doetsch, E. P.
Dole, Cora
Donaldson, J. Arthur
Donnelly, Mary
Dondlinger, P. T.
Dorn, F. L.
Doten, Carroll W.
Doughty, Howard W.
Douglas, R. L.
Dowd, Merritt C.
Downey, E. H.
Doysié, Abel
Drew, F. L.
Dubois, W. E. B.
Dugés, Alfred
Duggar, B. M.
Dunbar, F. J.
Dunbar, P. B.
Dupree, J. W.
Durand, A. C.
Durand, Alice M.
Durant, Aldrich
Dutra, J.
Dyer, George W.
Eakle, A. S.
Earl, Charles B.
Eastman, Guy W.
Eaves, Lucile
Eckel, Edwin C.
Eckerson, Jr., Theodore H.
Edgerton, C. E.
Edwards, Alba M.
Egbert, Ella E.
Einenkel, Eugene
Eliason, A. C.
Ellenbogen, A.
Ellis, C. W. H.
Ellison, J. W.
Elvove, Elias
Ely, Richard T.
Emmons, W. H.
Endsley, L. E.
Engle, S. G.
Erbach, John
Essex, Herbert
Esslinger, E. W.
Evans, H. B.
Everingham, Sumner
Everett, Milton
Failor, H. V.
Fairbanks, H. W.
Fairchild, Fred R.
Fairchild, H. P.
Falk, K. G.
Falsey, M. F.
Farragher, P. V.
Faust, A. B.
Ferry, Edna L.
Fessenden, E. Muriel
Fewkes, J. W.
Field, Arthur S.
Fisher, James
Fiske, Augustus H.
Fitch, J. L.
Fleisher, Moyer S.
Fleming, Oliver P.
Fleming, W. L.
Fletcher, F. P.
Flisch, Julia A.
Fontarede, Bertha A.
Forbes, S. A.
Foreman, J. C.
Fowke, Gerard
Fowle, F. E.
Fox, Henry
Francis, Luva
Francis, William I.
Frazer, J. C. W.
Frederick, C. W.
Freedlander, A. A.
Fredlund, Miss I. S.
Frevert, H. L.
Fristoe, Edward B.
Frye, T. C.
Fuld, Leonhard F.
Fulton, F. P.
Fulton, H. R.

Furey, Mrs. S.
Gage, Phelps
Gager, C. Stuart
Gale, Roger D.
Gardner, R. H.
Garret, A. O.
Garrey, G. H.
Garrison, Eleanor
Garrison, Florence
Garrod-Thomas, Richard N.
Gates, R. R.
Gavin, Lillie
Gavin, Margaret
Geer, R. R.
Gervasi, Arturo
Gephart, W. F.
Getman, Frederick H.
Gibbs, George (a)
Gibbs, R. C.
Gielow, Henry J.
Giesecke, Albert S.
Gifford, Ralph S.
Gilbert, James H.
Gilbert, Walter M.
Giles, Wesley
Gill, E. E.
Gill, Miss M. A.
Gilliland, Ada
Gilmore, E. A.
Girty, George H.
Githens, Thomas S.
Glaser, C.
Gleason, H. A.
Glocker, C. H.
Glocker, T. W.
Gloetzner, Arnulf R.
Glynn, Vernon W.
Goldenweiser, E. A.
Goldfarb, Abraham
Goldman, M.
Gooch, F. A.
Goodrich, Julia I.
Graham, David E.
Graham, J. G.
Graton, L. C.
Gray, L. C.
Greeley, Arthur W.
Grey, Irving M.
Griffin, Bertha
Griffin, Frank L.
Griffin, Grace G.
Griffin, Lawrence E.
Griffith, Elmer C.
Grimsley, G. P.
Groat, George G.
Groesbeck, Edward C.
Groesbeck, W. S.
Groosenberg, Michel
Gudernatsch, T.
Gudger, E. W.
Guernsey, S. Florence
Guest, H. H.
Gulik, Addison
Guthrie, G. B.
Guthrie, Joseph
Hackett, H. A.
Hadley, P. B.
Hagerty, J. E.
Haig, Robert M.
Haines, M. A.
Hall, Byran D.
Hallett, Emma C.
Halpin, R. J.
Hamer, W. C.
Hammond, M. R.
Hancock, Glover D.
Hand, J. W.
Haney, Lewis H.
Hanna, Hugh S.
Harder, F. W.
Hargitt, George T.
Harkins, William D.
Harkness, Arthur W.
Harned, Joseph E.
Harriman, Miss M. E.
Harris, Calvin
Harris, Gorham W.
Harris, J. F.
Harrison, Miss J. P.
Harshaw, Jr., Frank
Hartley, Carl P.
Hartman, R. R.
Haseman, J. D.
Haskell, Raymond
Hatai, S.
Hayes, J. T.
Hayes, Robert
Hayford, J. F.
Heaney, C.
Hedrick, H. M.
Hedrick, Wilbur O.
Hefferman, William H.
Heim, William
Helleberg, Victor E.
Henderson, L. J.
Henderson, W. D.
Henry, L. G.
Herriott, Frank I.
Herron, Belva M.
Hess, R. H.
Hess, William
Hesselberg, Theodor
Heth, Eva
Heyl, F. W.
Hibbard, B. H.
Hibbard, Stella
Hill, Richard S.
Hinds, Mrs. E. G.
Hines, Murray A.
Hinkins, J. E.
Hinks, A. R.
Hitchcock, L. R.
Hitchen, W. K.
Hoagland, H. E.
Hobe, Adelaide M.
Hodgson, W. B.
Hoffman, E. J.
Hoffman, G. F.
Hoffman, G. R.
Holcomb, Wilber
Holden, R. J.
Holdredge, L. I.
Holdsworth, J. T.
Holland, W. W.
Hollander, Jacob H.
Holmes, A. D.
Holway, R. S.
Hönigschmid, Otto
Hooker, John D.
Hoover, Charles R.
Hopkins, Bertha E. A.
Hopkins, B. S.
Hornbeck, J. W.
Hoskins, L. M.
Houghton, Mrs. L. S.
Houston, C. J.
Howe, C. D.
Howe, H. E.
Howell, Warren
Howell, William H. (a)
Hübschmann, Oscar
Huebner, G. G.
Huebner, S. S.
Hughes, E.
Hunt, Burgess
Hunt, Franklin L.
Huntington, C. C.
Hurlbutt, Mary F.
Hus, Henri
Husbands, Jose D.
Hussakof, Louis
Hussey, Harry H.
Hussey, W. J. (a)
Hyde, Elizabeth A.
Ingalls, Walter R.
Ingersoll, Leonard R.
Ingram, Charles I.
Irby, R. G.
Isely, W. H.
Isaacs, Nathan T.
Ives, H. E.
Jack, Theodore H.
Jackson, Frederick G.
Jackson, Richard F.
Jacob, T. H.
James, W. E.
Jansson, E. W.
Jay, Frank
Jefferson, Lorian P.
Jellinek, George
Jenson, G. H.
Jepson, W. L.
Jesse, Jr., R. H.
Johannsen, O. A.
Johnson, B. G.
Johnson, D. C.
Johnson, Hilma
Johnson, Henrietta R.
Johnson, J. M.
Johnson, John N.
Johnston, R. H.
Jolley, L. H.
Jones, C. C.
Jones, Chester L.
Jones, D. B.
Jones, Edward D.
Jones, George D.
Jones, Grinnell
Jones, Henry L.
Jones, T. J.
Jones, William

Jorden, Stroud
Jorgensen, Alfred
Joslin, Lulu B.
Jost, J.
Kanolt, C. W.
Kato, Yogoro
Keefer, Pearl M.
Keiller, V. H.
Kellicott, William E.
Kelly, Thomas E.
Kemp, R. H.
Kemple, J. E.
Kendrick, B. B.
Kennard, F. L.
Kennedy, J. B.
Kennon, W. L.
Keyes, Henry
Kick, William
Kidder, Homer
Kimball, Alice
Kimball, Gertrude S.
King, Cyrus A.
King, Claude F.
King, Clyde L.
King, Helen D.
Kinney, W. L.
Kittredge, Elizabeth M.
Kleihege, George W.
Klein, Julius
Knight, H. L.
Koch, Julius A.
Kofoid, C. H.
Korselt, Johannes
Kowalke, Otto L.
Kraemer, Henry
Kubel, S. J.
Kuntz, William
Lafora, Gonzalo R.
Lambert, Avery E.
Lambert, F. D.
Landis, W. S.
Lane, Henry H.
Laney, F. B.
Lantz, A. W.
Lapp, John
Larson, Laurence M.
Lawrence, J. W.
Lawrence, William H.
Leavenworth, C. S.
Leavell, R. H.
Leavitt, Henrietta S.
Lee, Henry G.
Lefevre, George
LeGrand, J. M.
Leith, C. K.
Leland, Miss E. F.
Leonard, A. A.
Leopold, S.
Leslie, W. H.
Leutscher, George D.
Levene, Phoebus A.
Levy, A. G.
Lewis, H. M.
Lewis, Ivey N.
Lewis, Warren H.
Liddle, L. M.
Lindau, L.
Linde, Curtis
Lindsay, C. F.
Lippincott, I. P.
Lipski, Morris
Little, C. C.
Littlefield, C. E.
Livingston, Jennie D.
Lockhart, Oliver C.
Lockwood, Edna K.
Lombard, Guy D.
Lombard, Robert H.
Lommen, Christian P.
Longley, W. R.
Loomis, N. E.
Loos, I. A.
Lorenz, J. N.
Lovelace, B. F.
Loveland, George A.
Lowry, Russell
Loy, S. K.
Luders, E.
Lundblom, Ivan C.
Lundblom, Otto
Lundin, Laura M.
Lutz, Frances
Lynde, Carlton J.
Lynn, Ross W.
Lyons, R. E.
MacDowell, E. Carlton
Macfarlane, John M. (a)
MacGill, Caroline E.
Mackinnon, John A.
Macy, Leo
Magovern, T.
Mailey, Roy D.
Mallonee, W. S.
Manning, Charlotte R.
Marean, Parker E.
Marquette, W.
Marquis, J. C.
Marshall, Jr., E. K.
Marshall, H. W.
Martin, Frank B.
Martin, Isabel
Martin, Mary T.
Marvin, C. F.
Mason, Gertrude
Mathews, Joseph H.
Matthes, F. E.
Mattingly, Francis H.
Maverick, B.
McArthur, Lewis A.
McAtee, Waldo L.
McBain, W. J.
McCabe, David A.
McCallum, W. B.
McCarthy, Charles
McCarthy, William
McClelland, J. F.
McClung, C. E.
McClure, E. V.
McClure, Mary M.
McCollum, E. V.
McCoy, Miss K. F.
McCracken, Isabel
McCutchen, George
McDowell, Louise S.
McFarland, Raymond
McGhee, J. L.
McGlone, B.
McGowan, A. F.
McGown, Helen C.
McGregor, J. H.
McGuire, Joseph D.
McGuire, P. S.
McIntire, Albert T.
McKay, Amy J.
McKitrich, Reuben R.
McLean, S. J.
McLean, W. T.
McMaster, L.
McMurphy, James
McMurray, F. S.
McNamara, Helen E.
McVey, F. L.
McWilliam, Janet
Mead, Charles S.
Mears, B.
Meigs, Edward E.
Melcher, Arthur C.
Merriam, C. Hart (a)
Messer, Earl S.
Messerol, C. G.
Meyers, Milton K.
Milburn, R. M.
Miller, Edmund T.
Miller, W. Lash.
Millis, F. E.
Millis, H. A.
Mills, John
Mills, Robert
Mills, Rufus
Millsaps, Jefferson H.
Milner, R. D.
Minor, Marie L.
Mitchell, Miss E. G.
Mitchell, P. H.
Mitchell, T. W.
Mitchell, W. C.
Molby, F. A.
Moll, Otto
Mollison, Th.
Monossowitch, Anna
Moody, W. F.
Moonlight, Tom
Moore, Blaine F.
Moore, Charles J.
Moore, E. H. (a)
Moore, Fredrica C.
Moore, J. H.
Morgan, H. C.
Morgan, James C.
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